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**Ashida et al.**

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(54) **BAND-PASS FILTER**

USPC ..... 333/175, 185, 177  
See application file for complete search history.

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

**H01P 1/203** (2006.01)

**H03H 7/01** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H01P 1/20345** (2013.01); **H01P 1/2039** (2013.01); **H01P 1/20309** (2013.01); **H01P 1/20381** (2013.01); **H03H 7/0115** (2013.01); **H03H 7/0161** (2013.01)

(58) **Field of Classification Search**

CPC ..... H03H 7/0115; H03H 2001/0085; H03H 7/09; H01P 1/20345; H01P 1/20309

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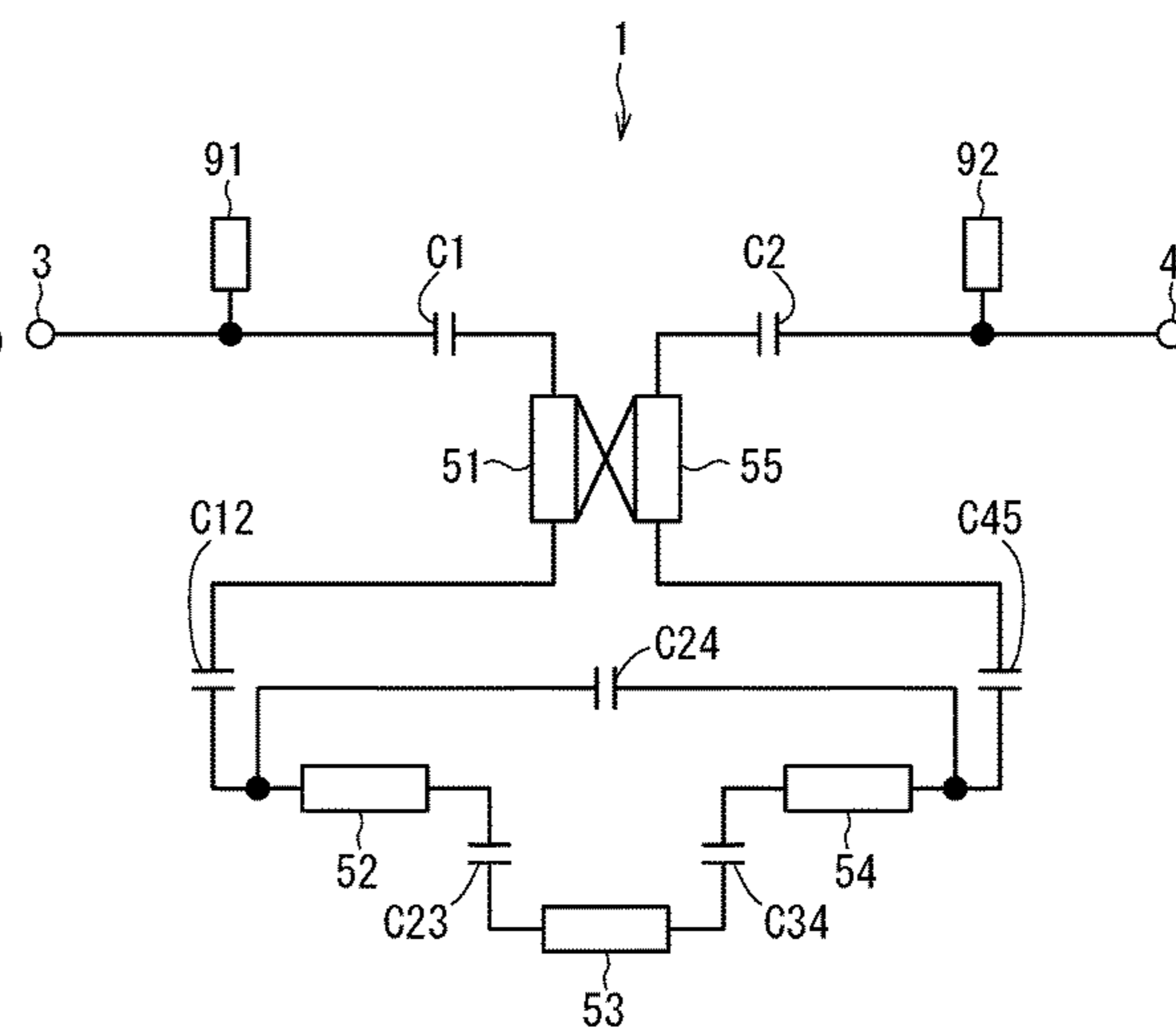
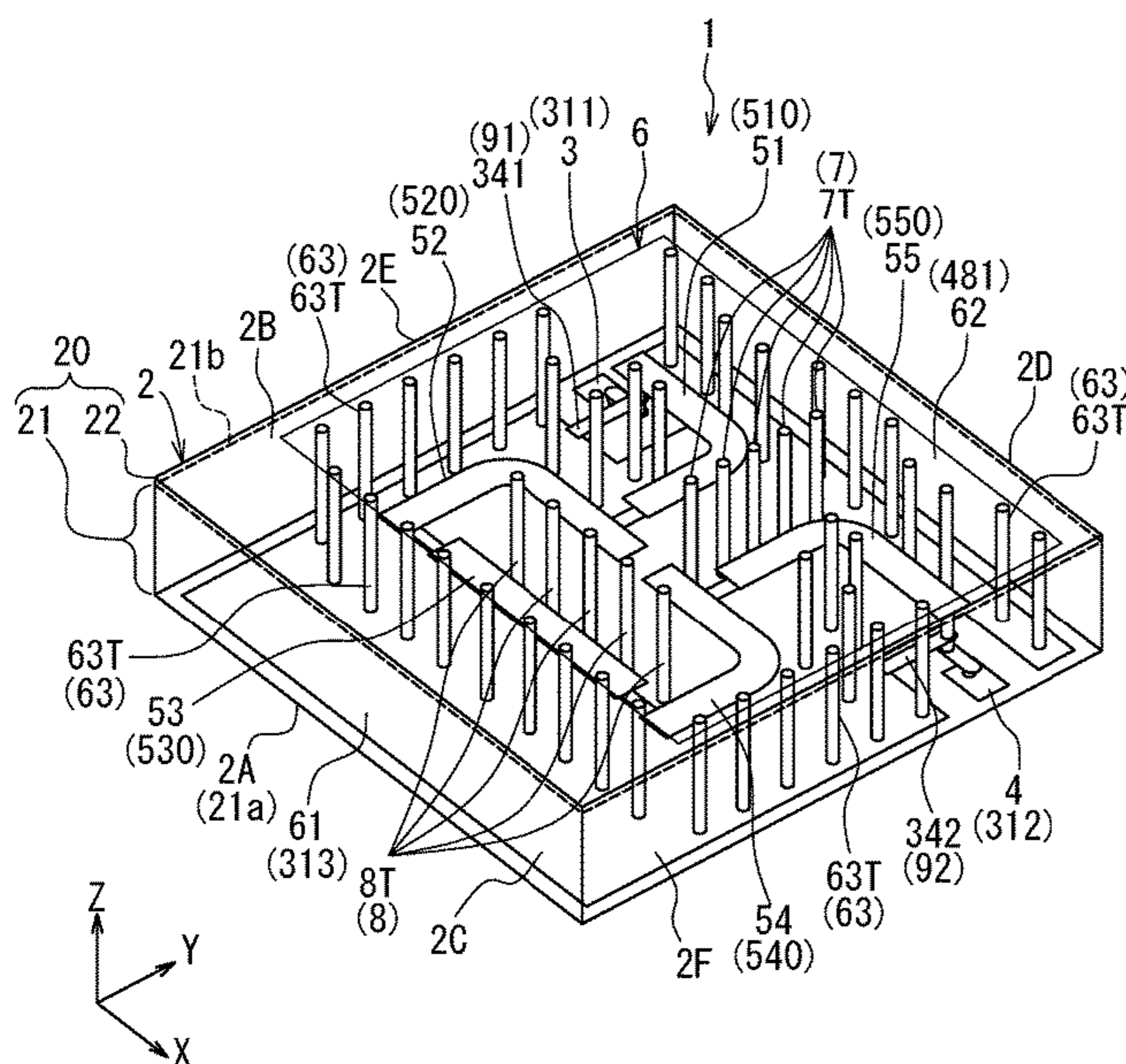
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(57) **ABSTRACT**

A band-pass filter includes a main body, five resonators, a shield, and a partition. The main body is formed of a dielectric. The partition is formed of a conductor. The five resonators are configured so that capacitive coupling is established between every two of the resonators adjacent to each other in circuit configuration. Each of the five resonators includes a resonator conductor portion. A first stage resonator and a fifth stage resonator are magnetically coupled to each other although not adjacent to each other in circuit configuration. The partition extends to pass between the respective resonator conductor portions of the first stage resonator and the fifth stage resonator, and is electrically connected to the shield.

**20 Claims, 18 Drawing Sheets**





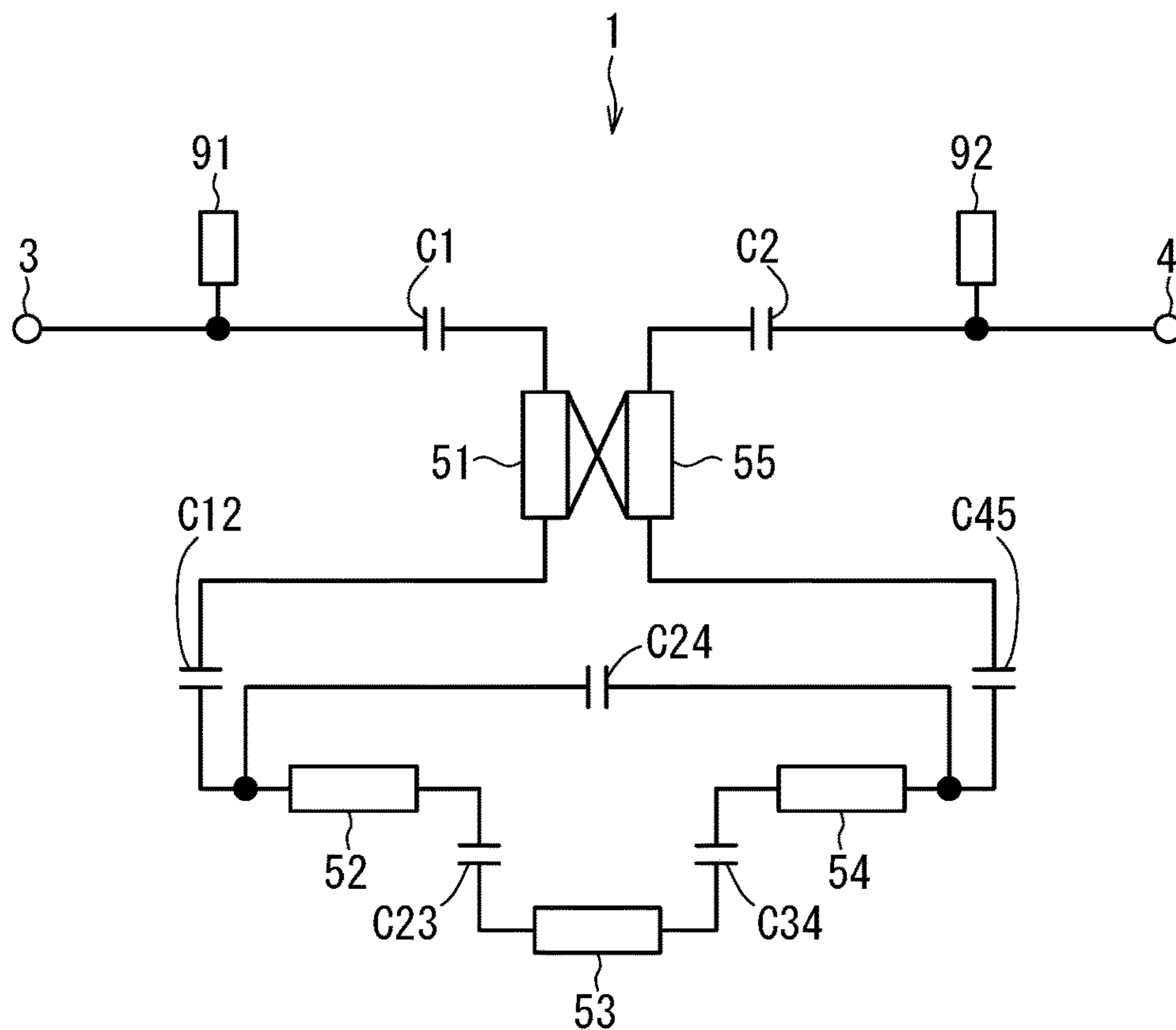


FIG. 2

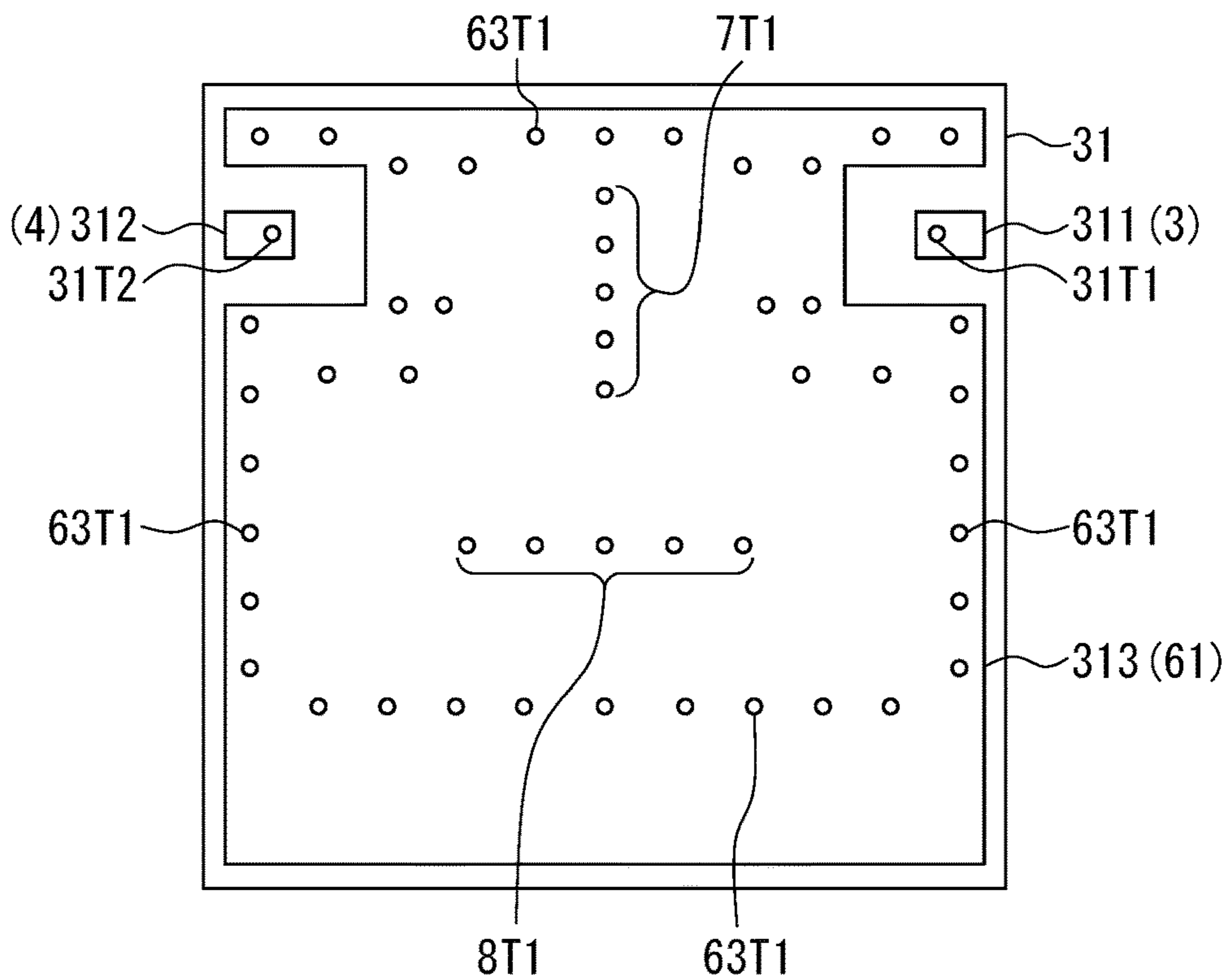


FIG. 3

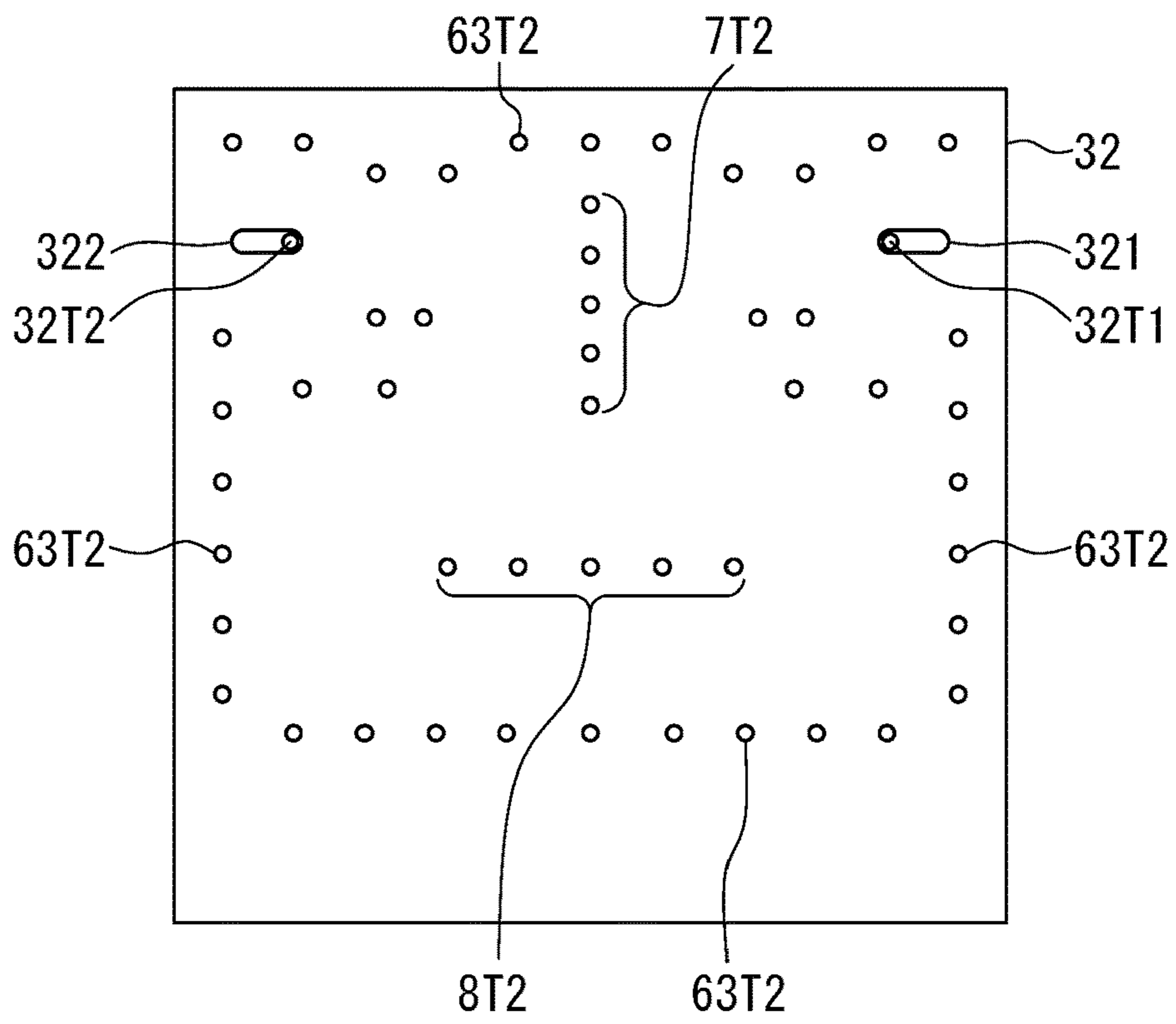


FIG. 4

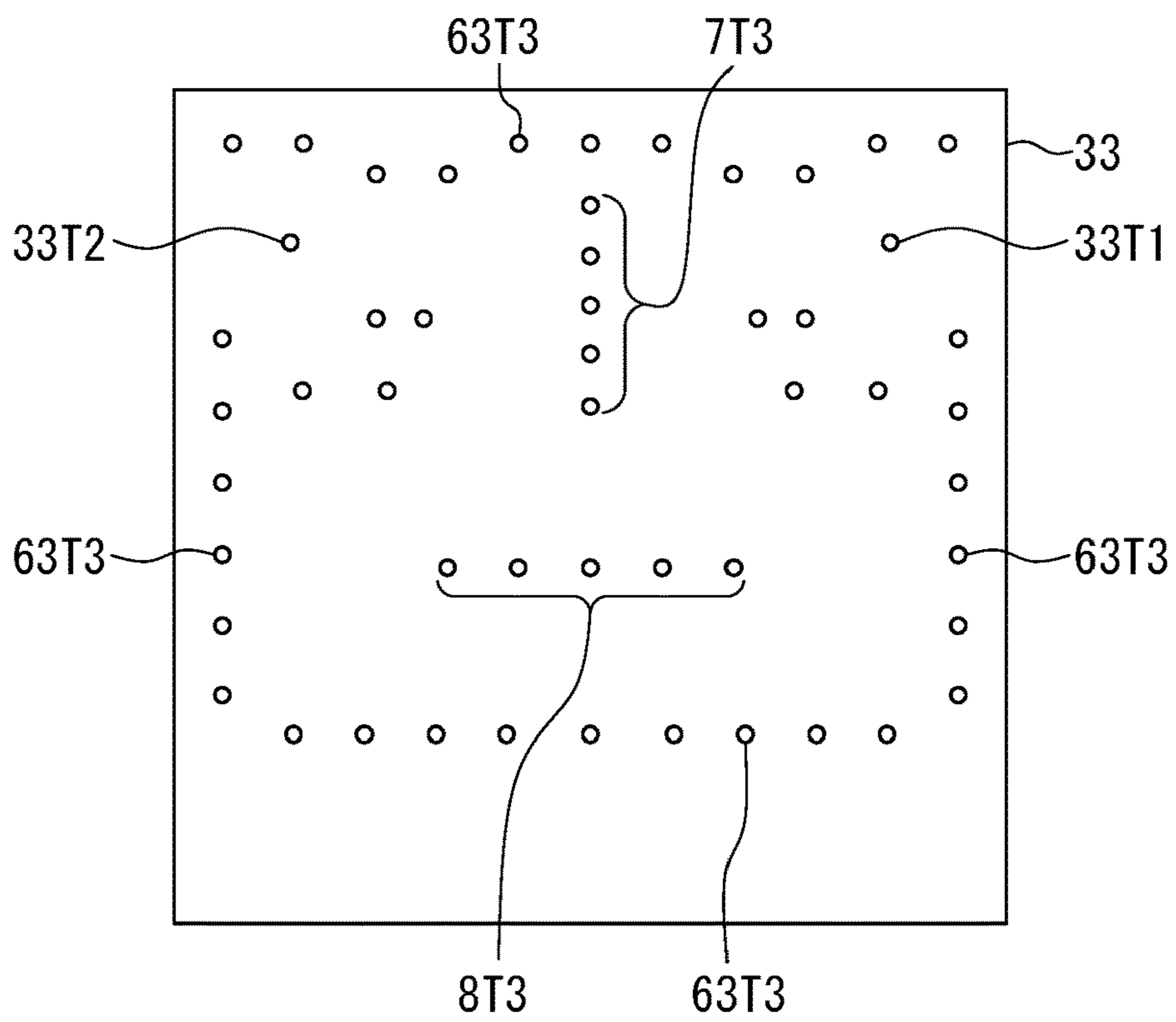


FIG. 5

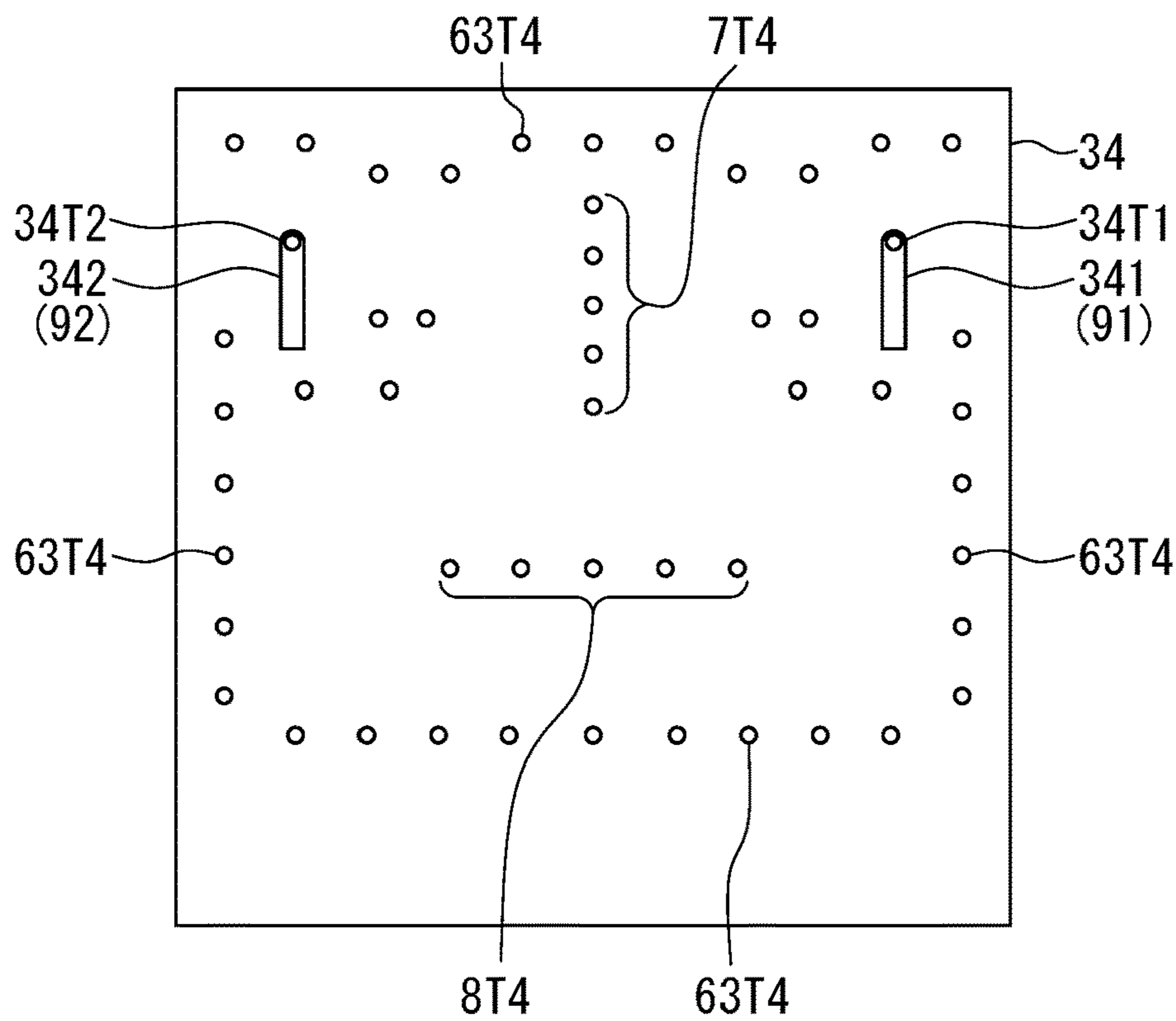


FIG. 6

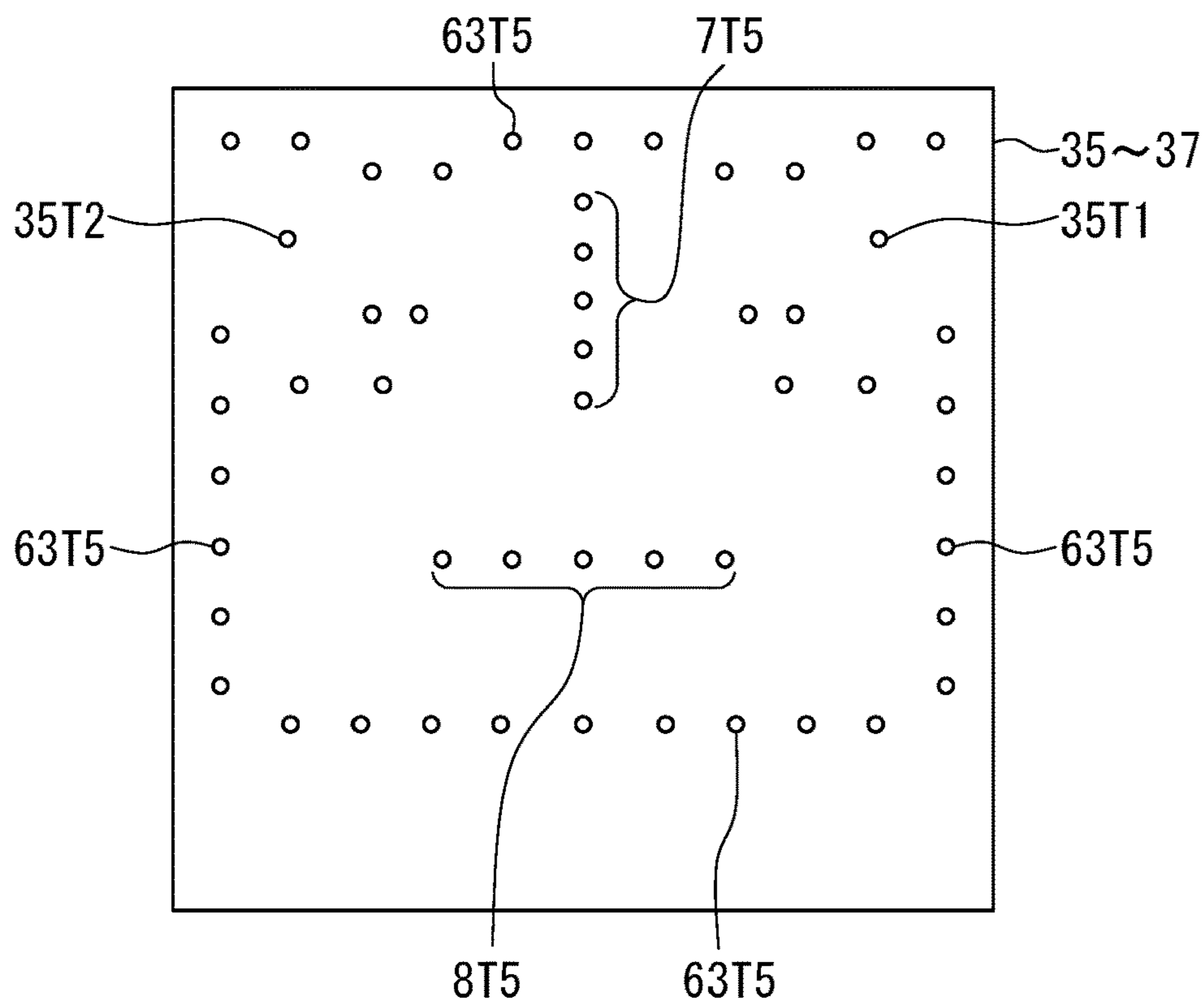


FIG. 7

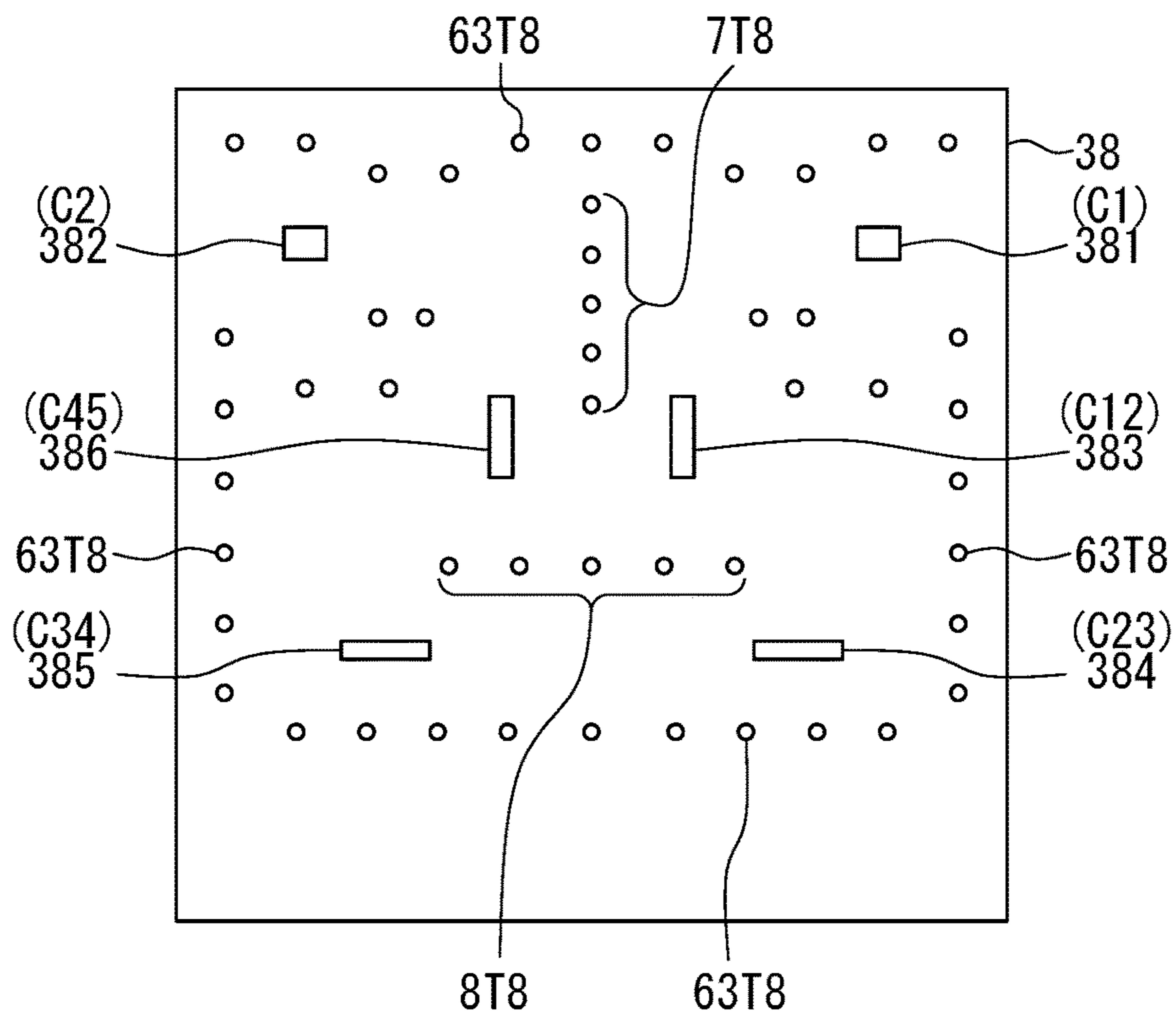


FIG. 8

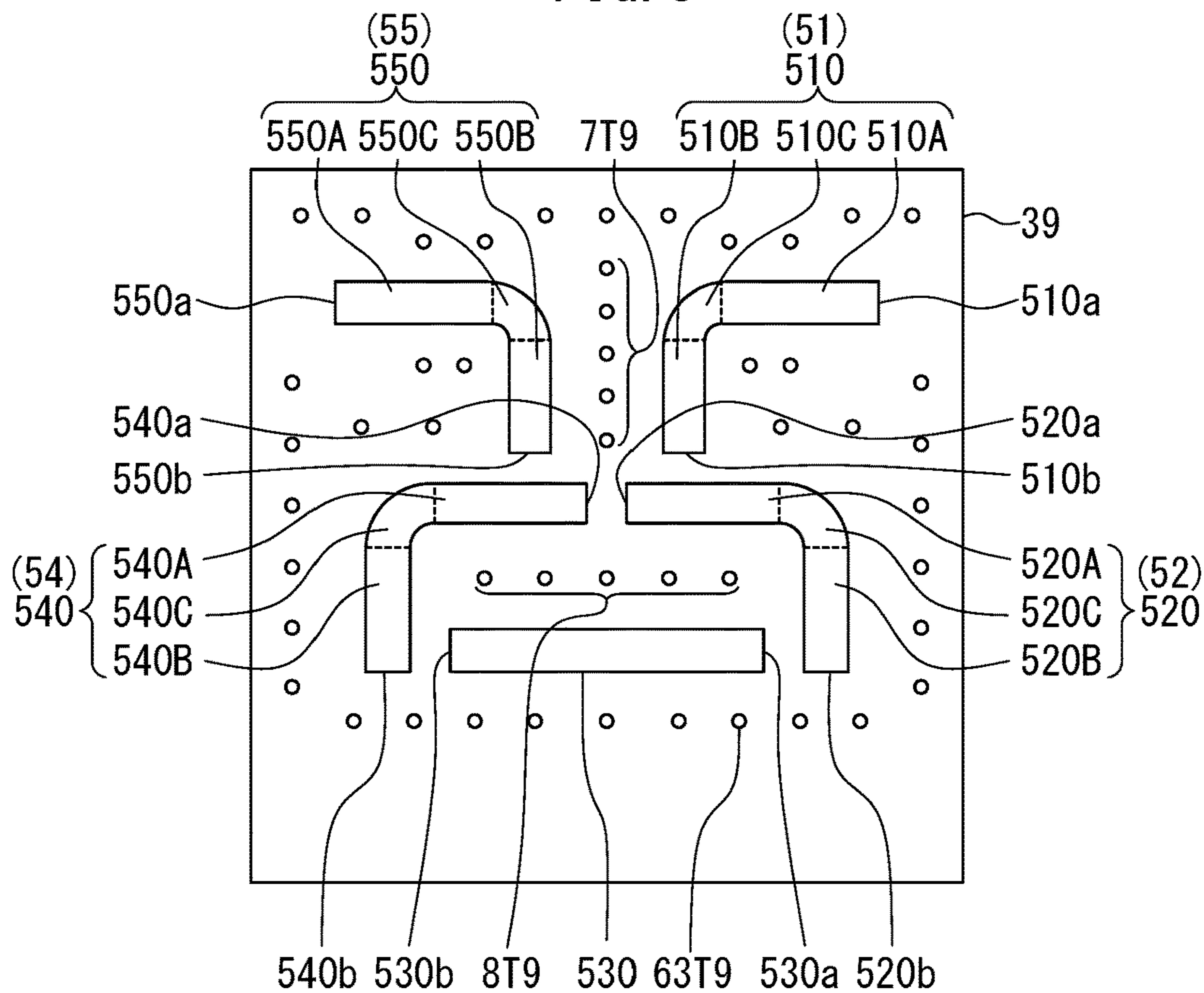


FIG. 9

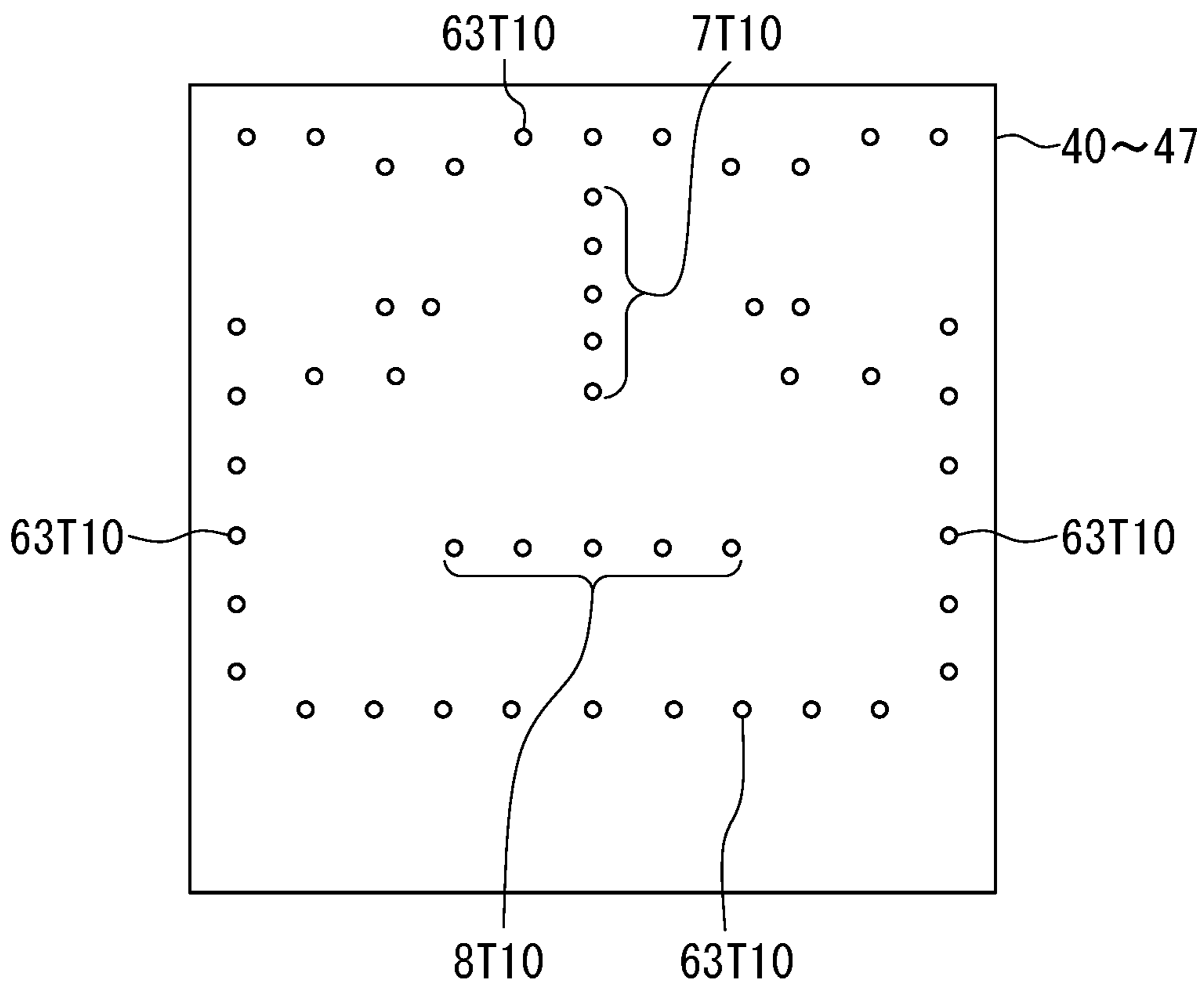


FIG. 10

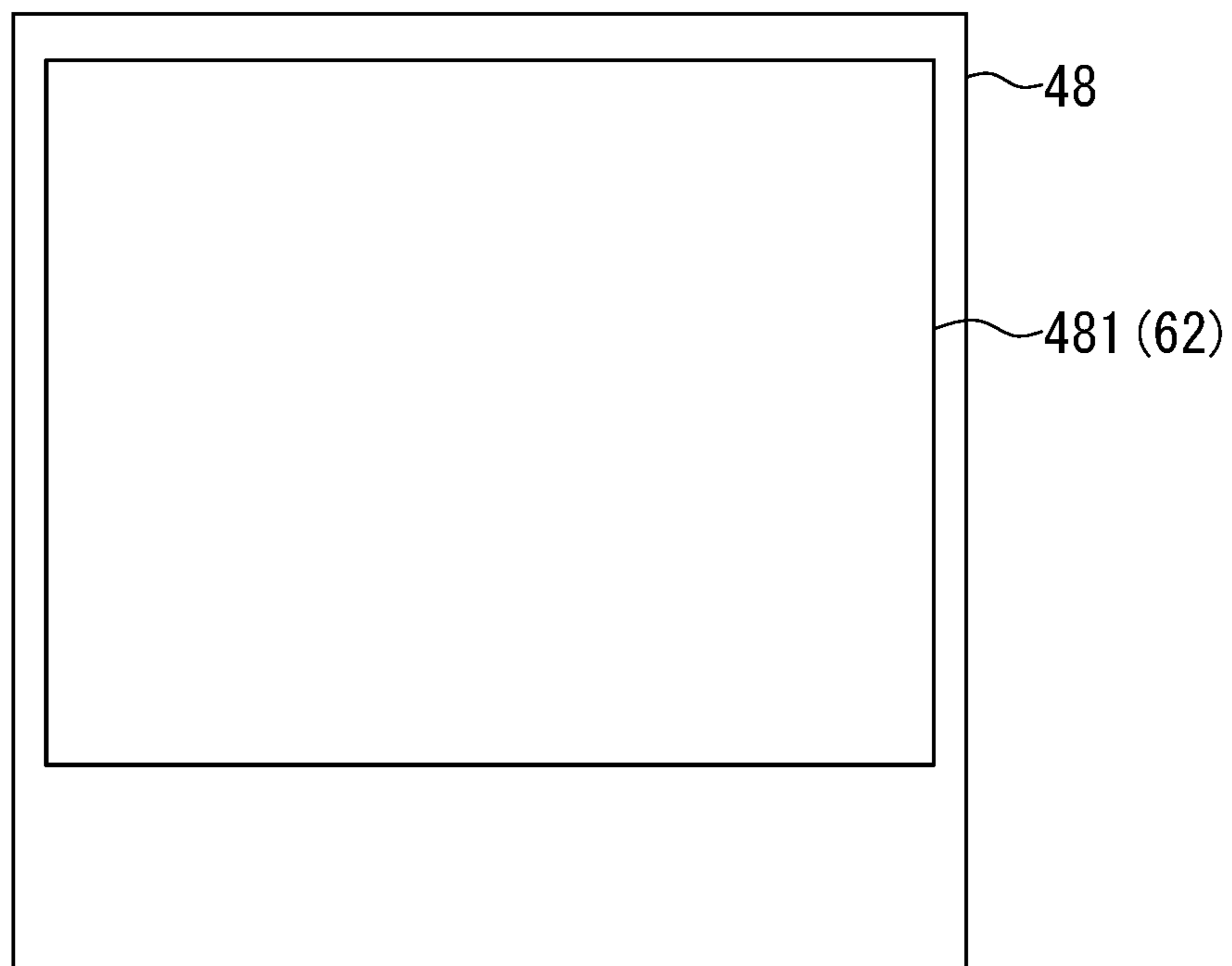


FIG. 11

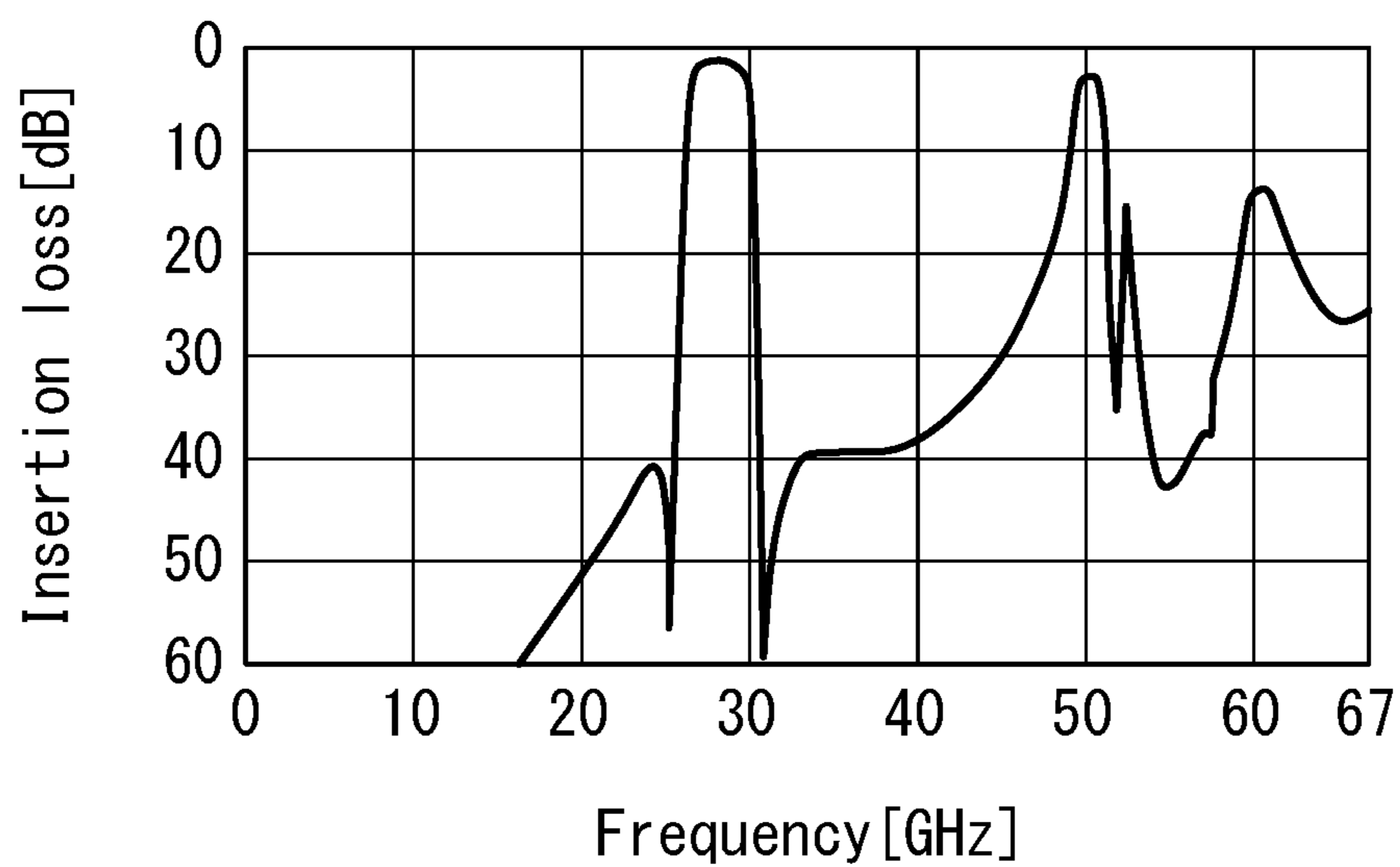


FIG. 12

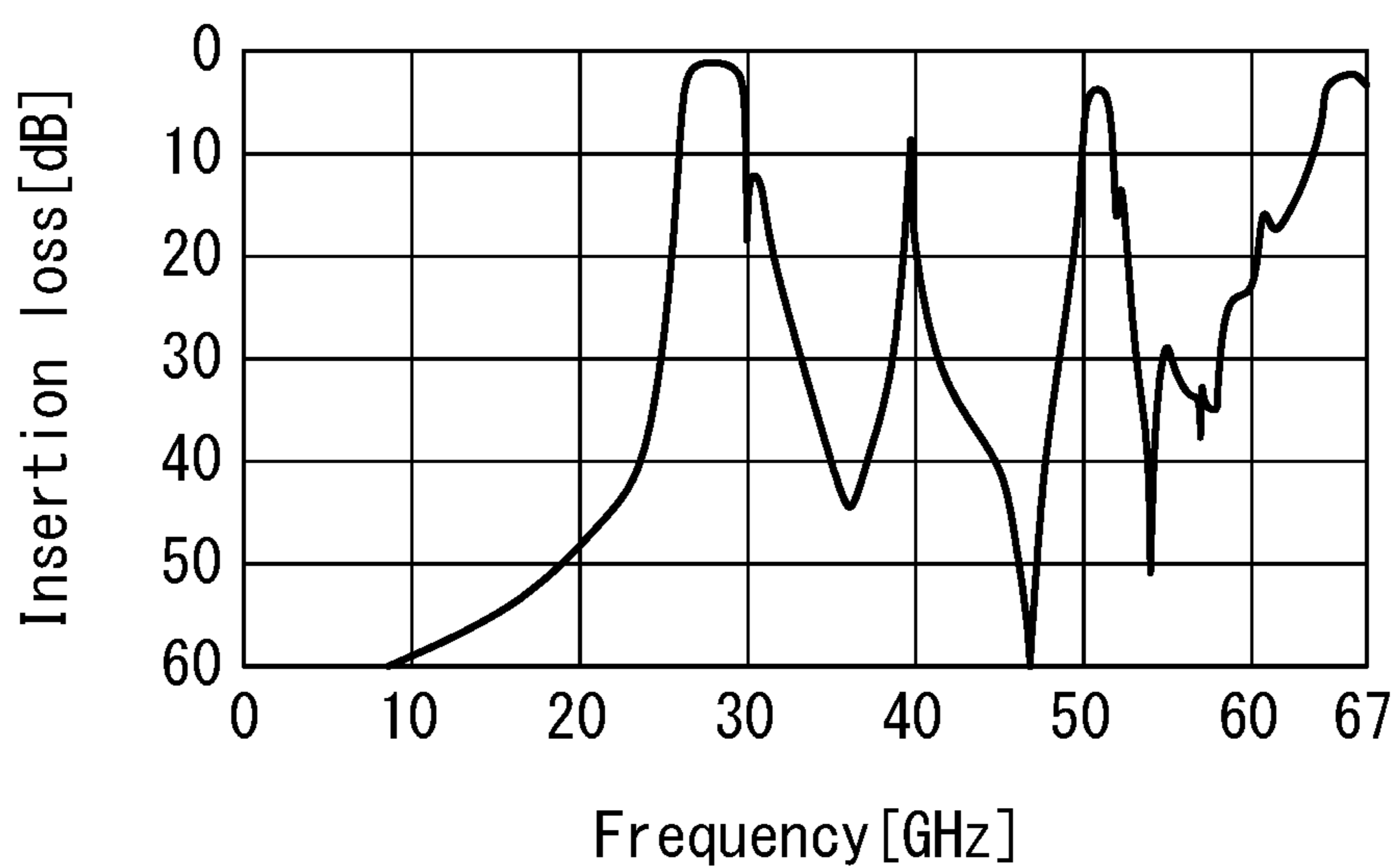


FIG. 13  
RELATED ART



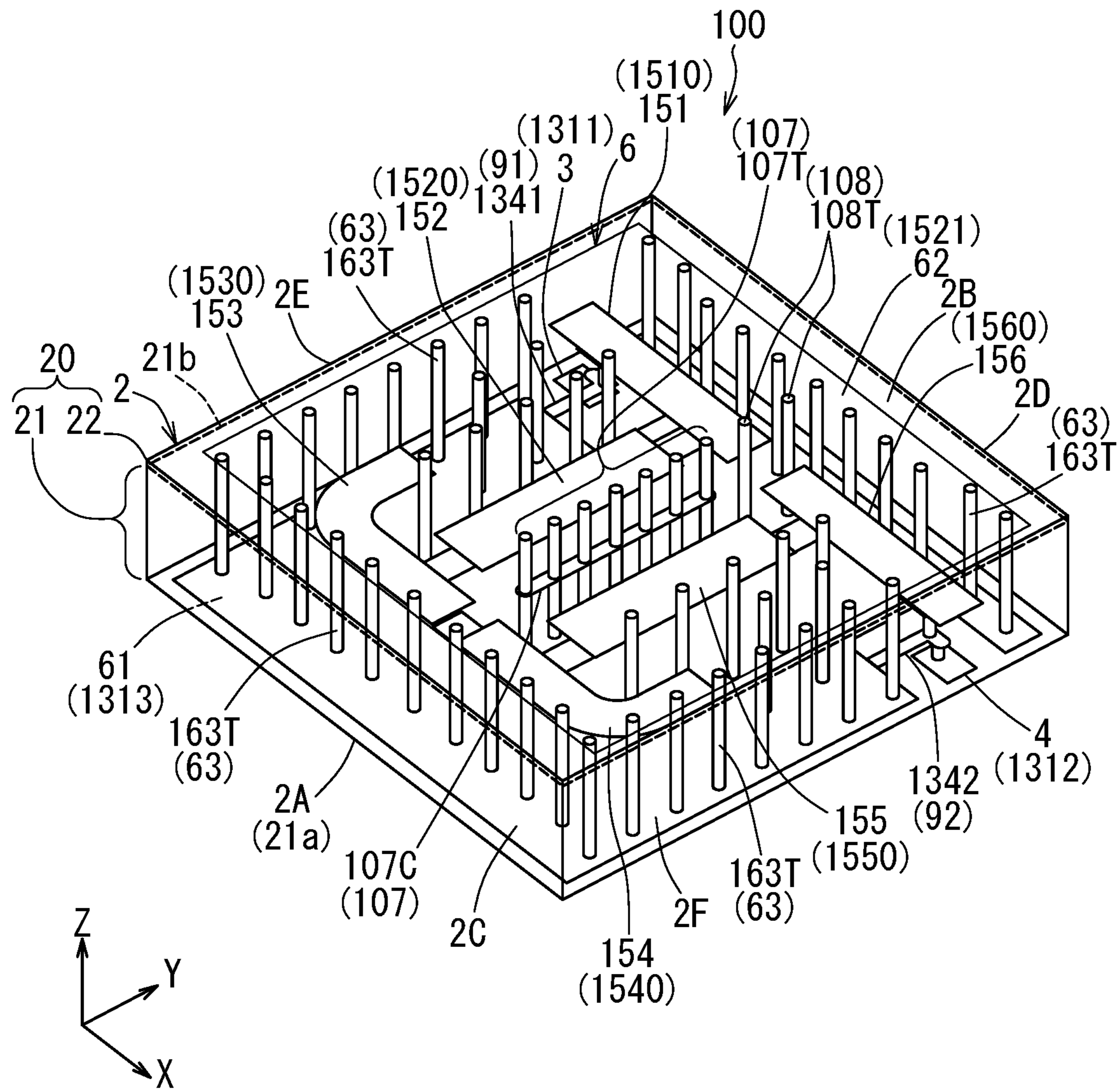


FIG. 14

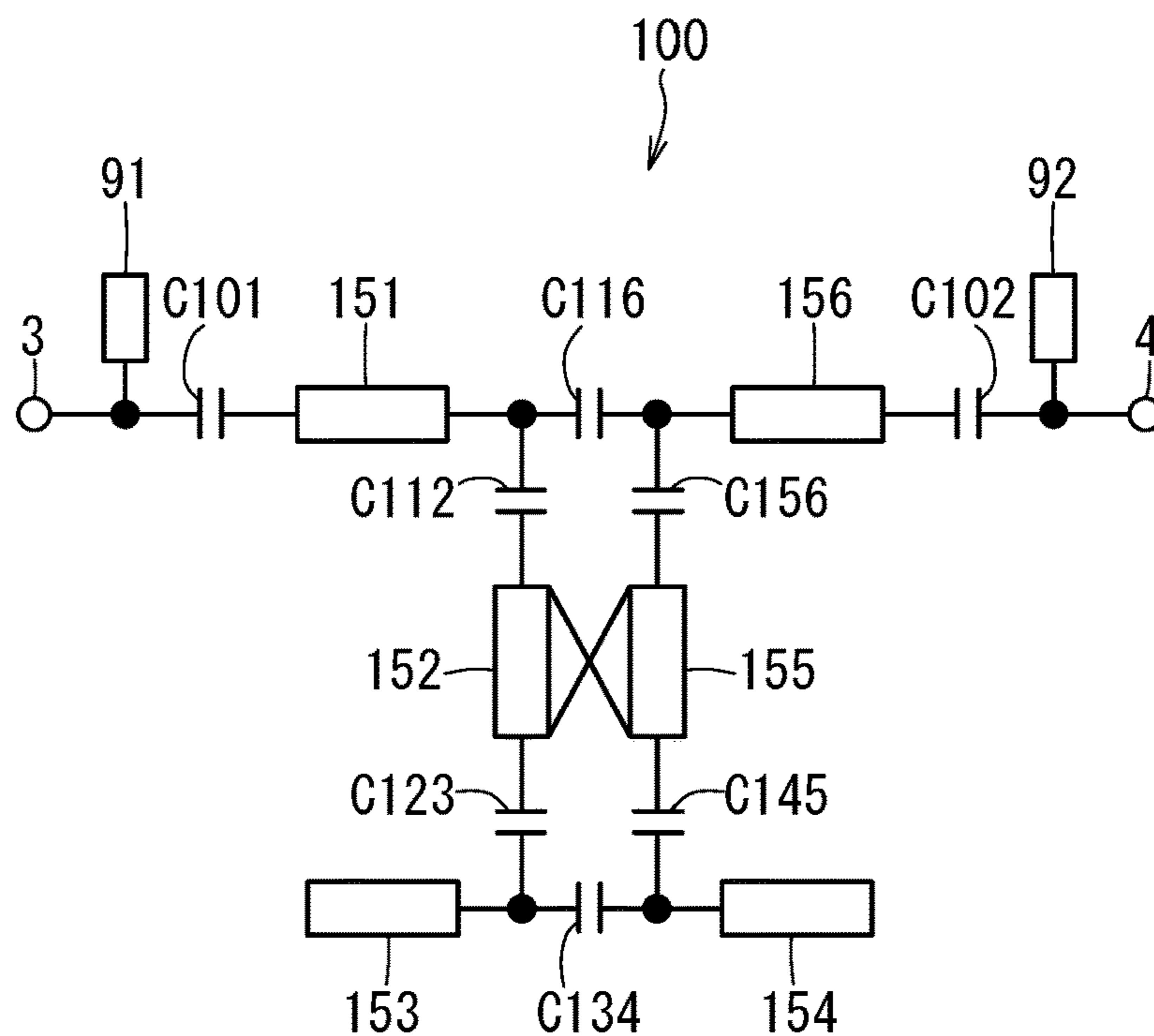


FIG. 15

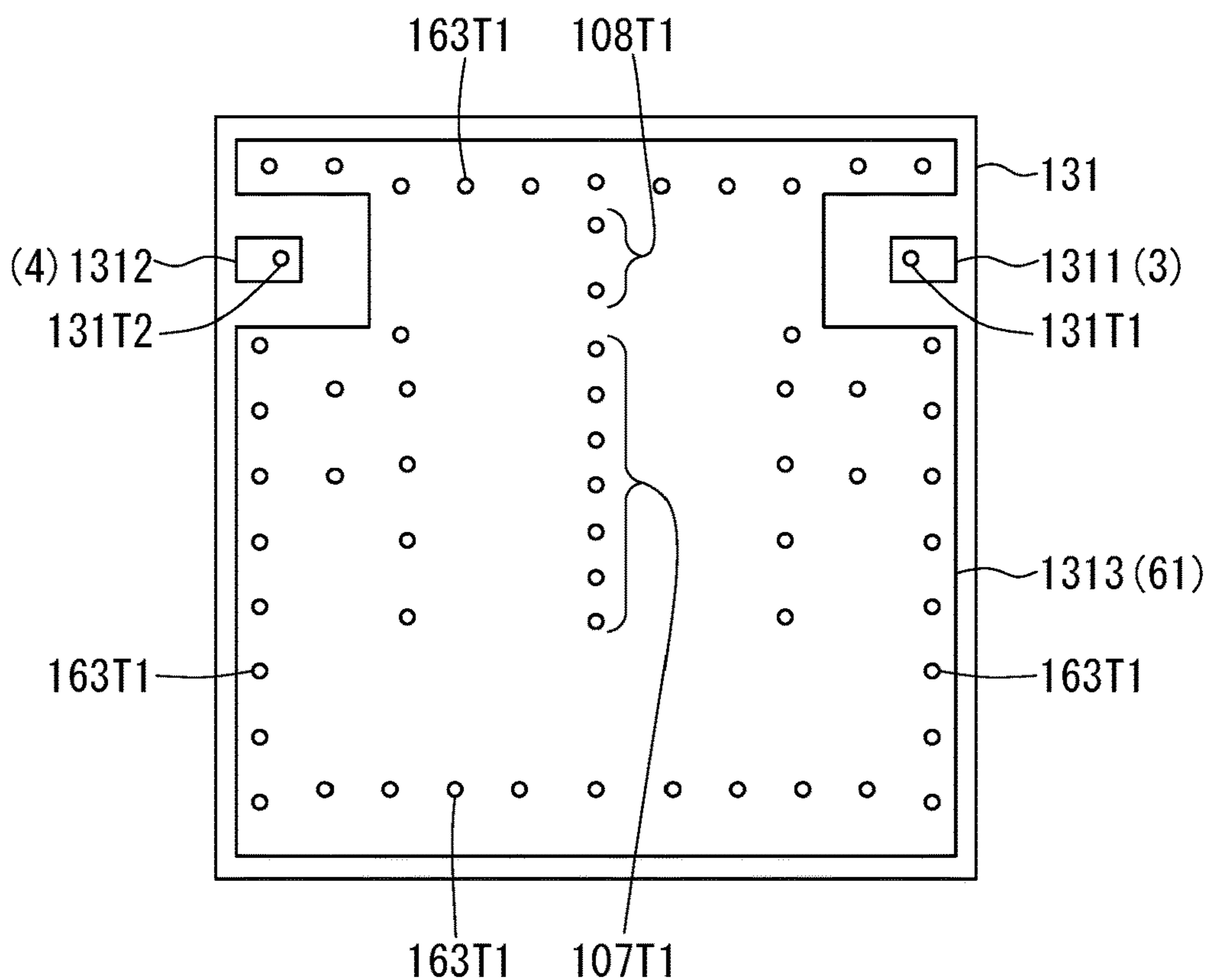


FIG. 16

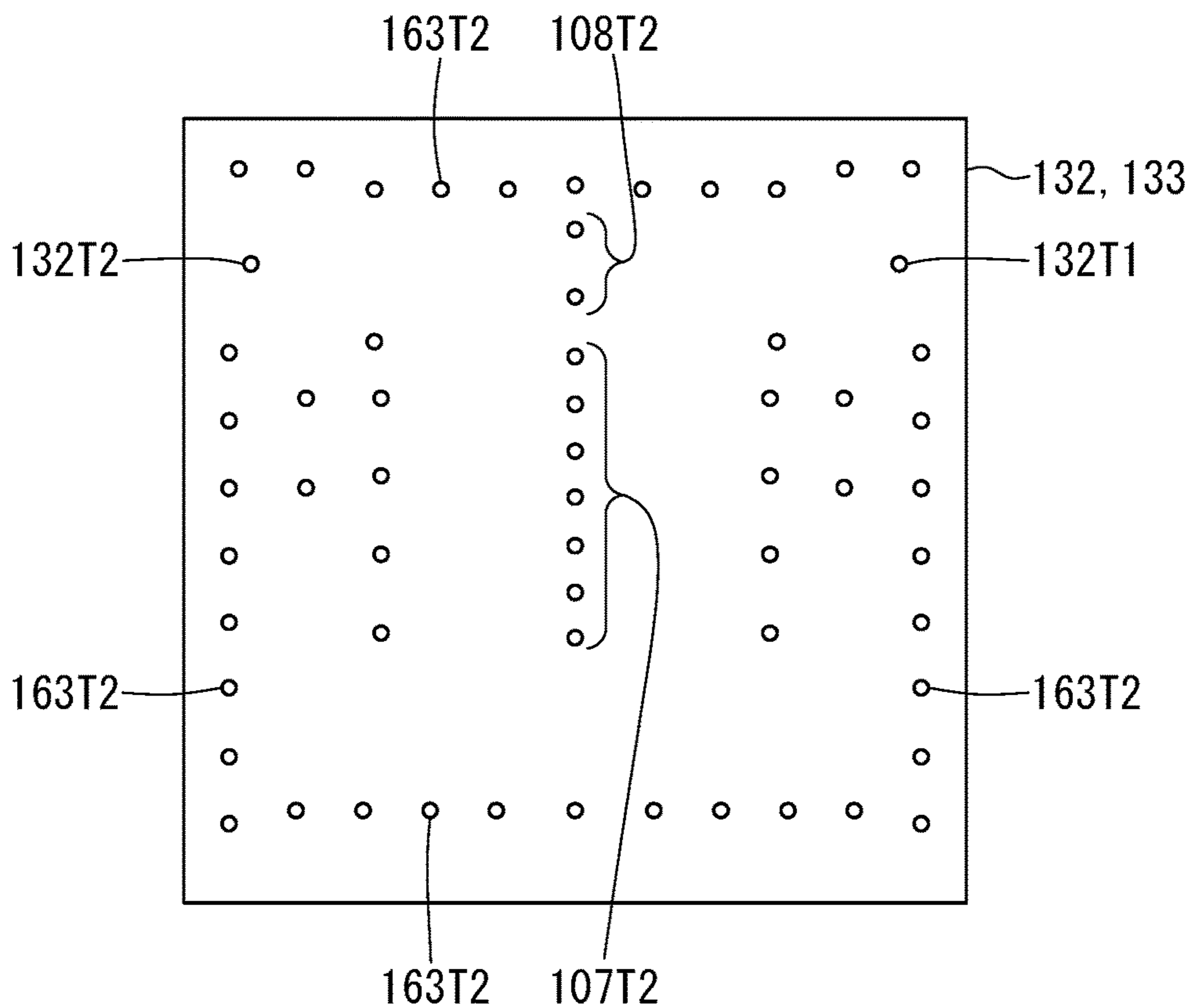


FIG. 17

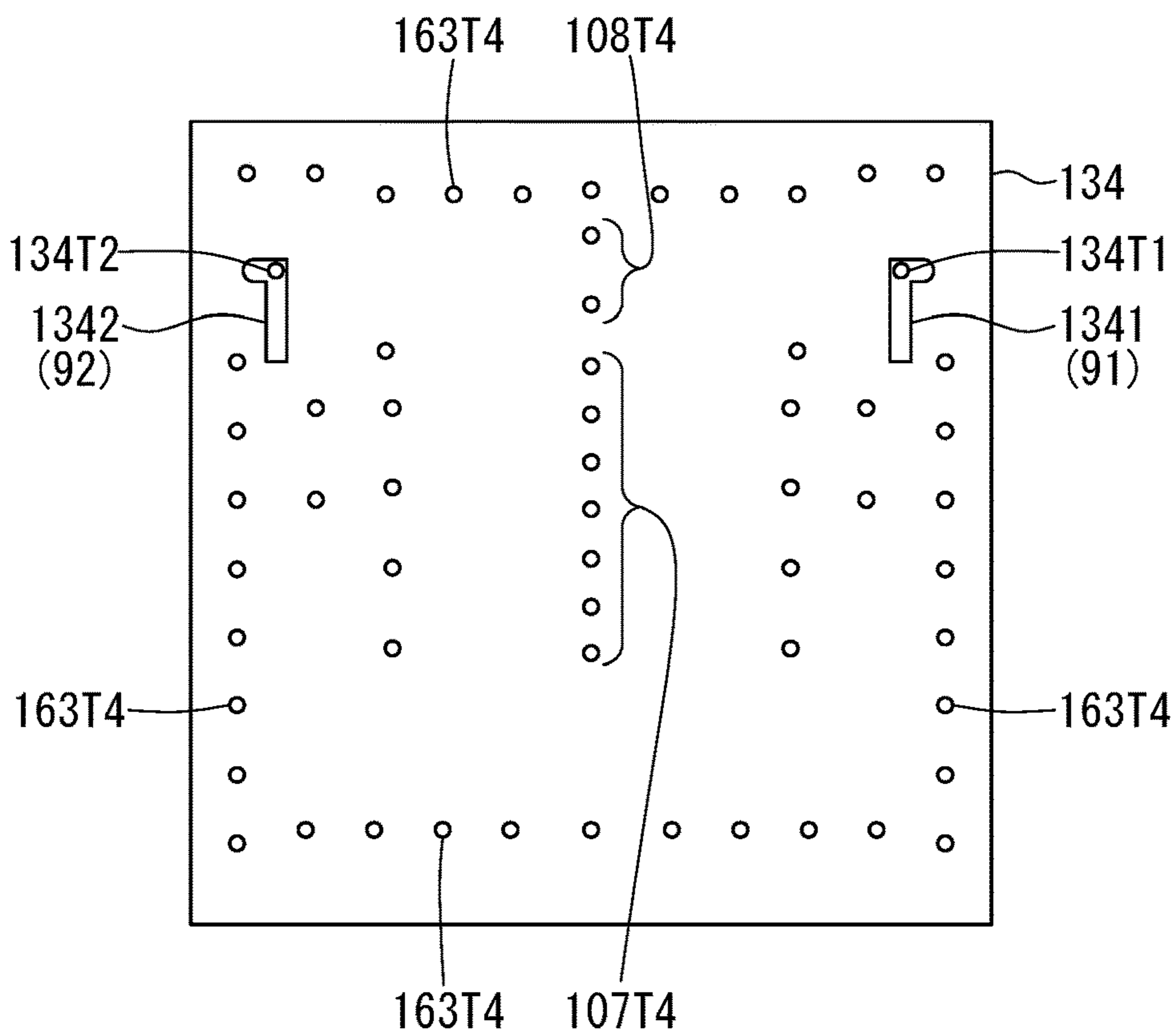


FIG. 18

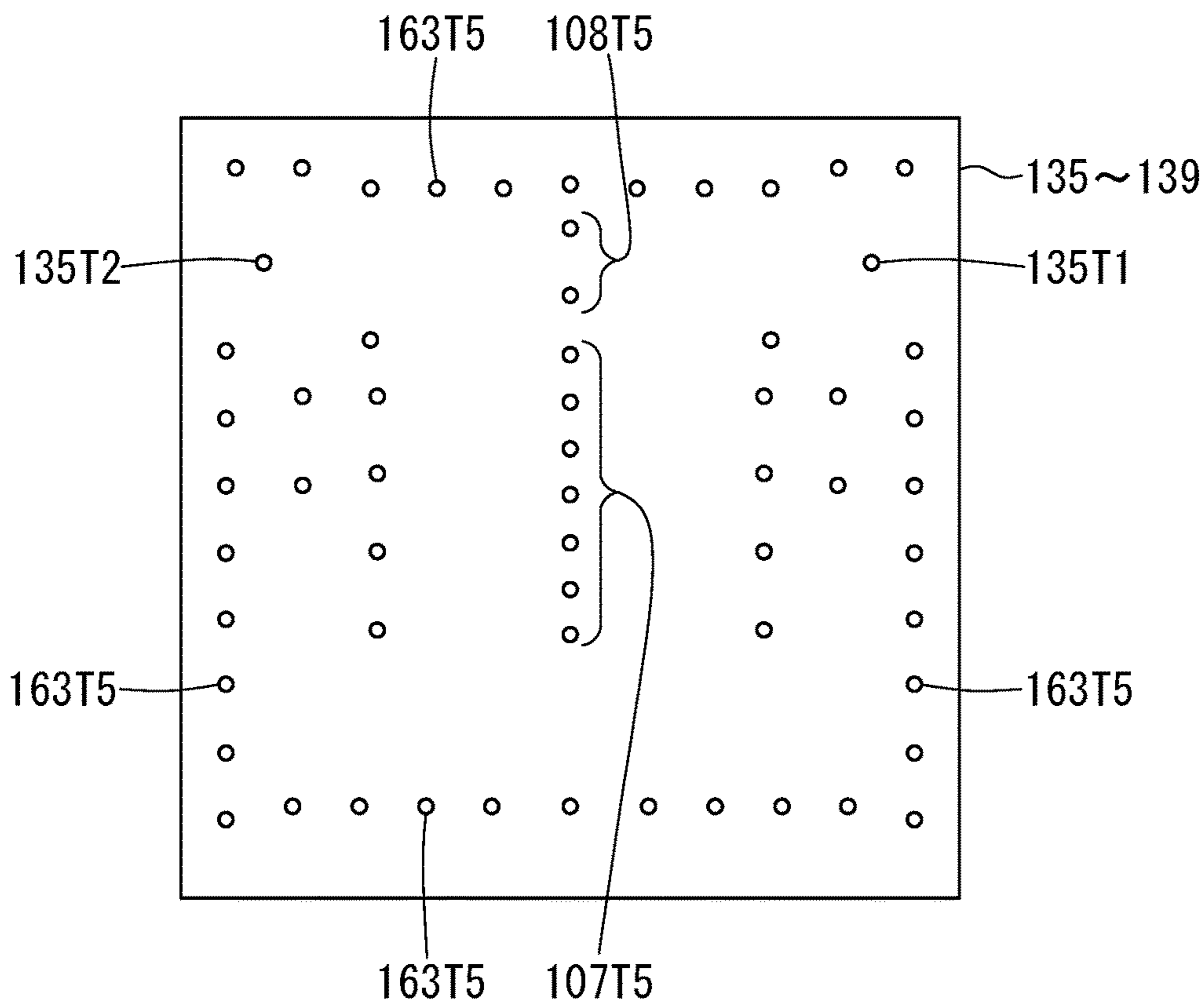


FIG. 19

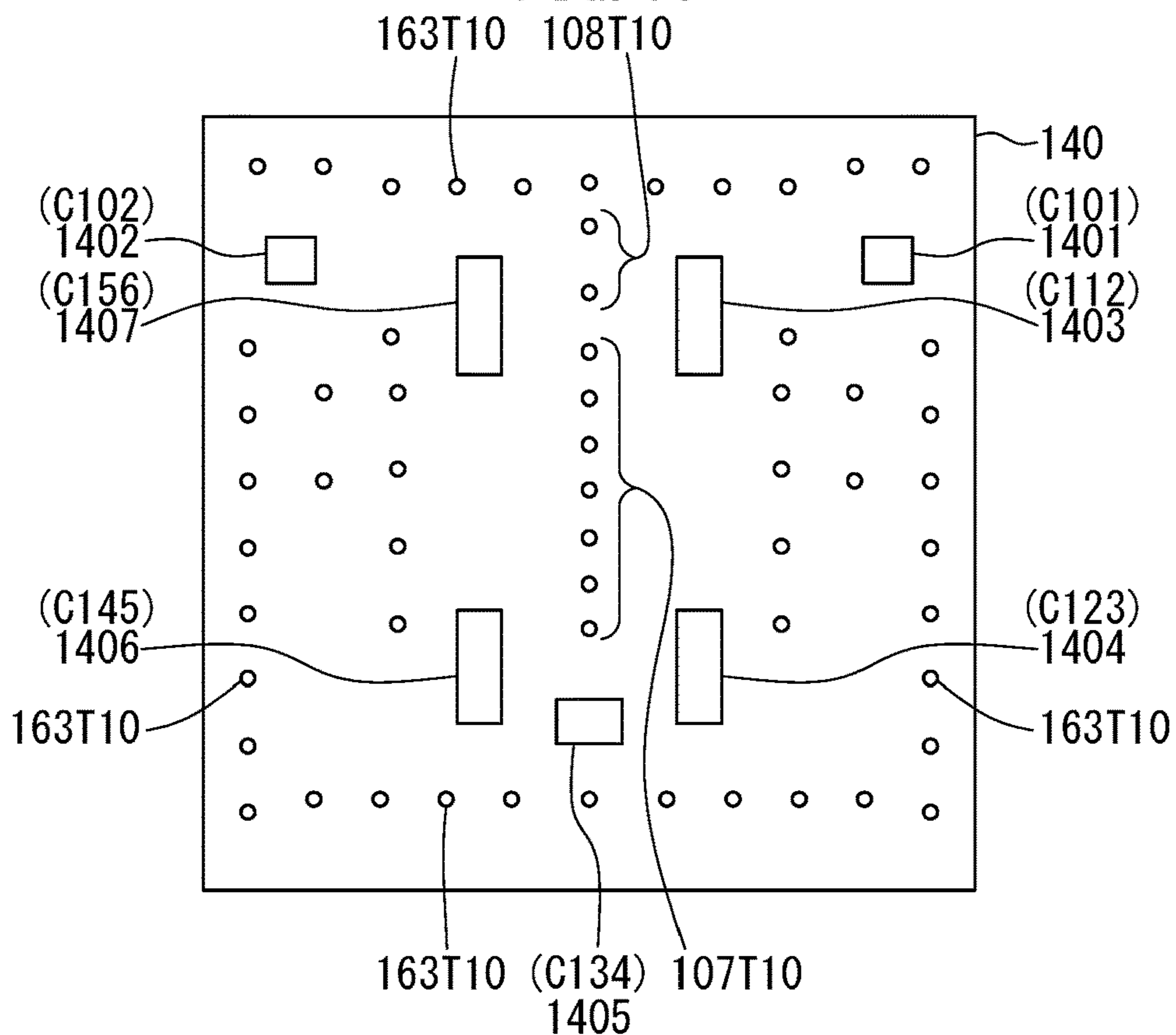


FIG. 20

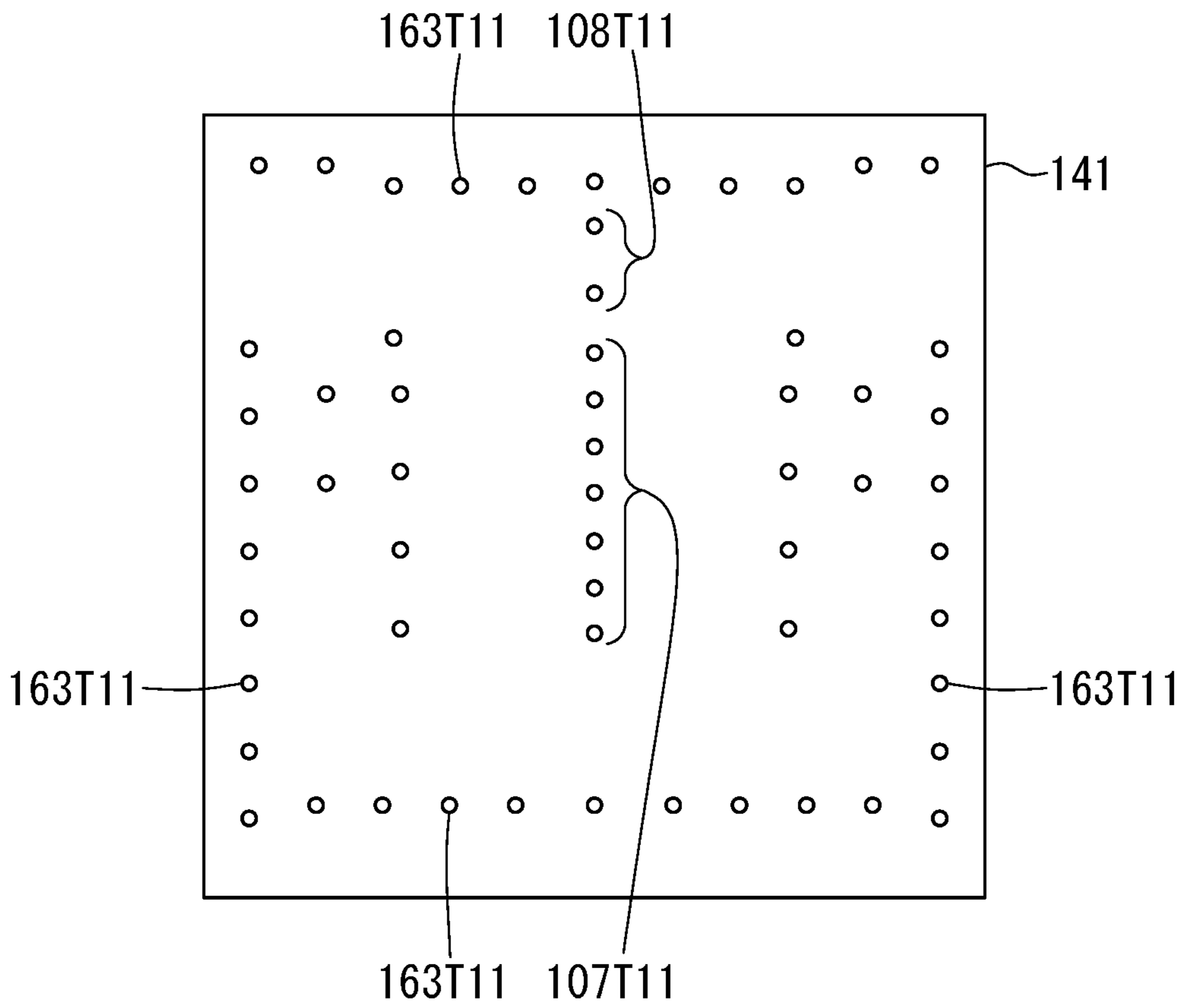


FIG. 21

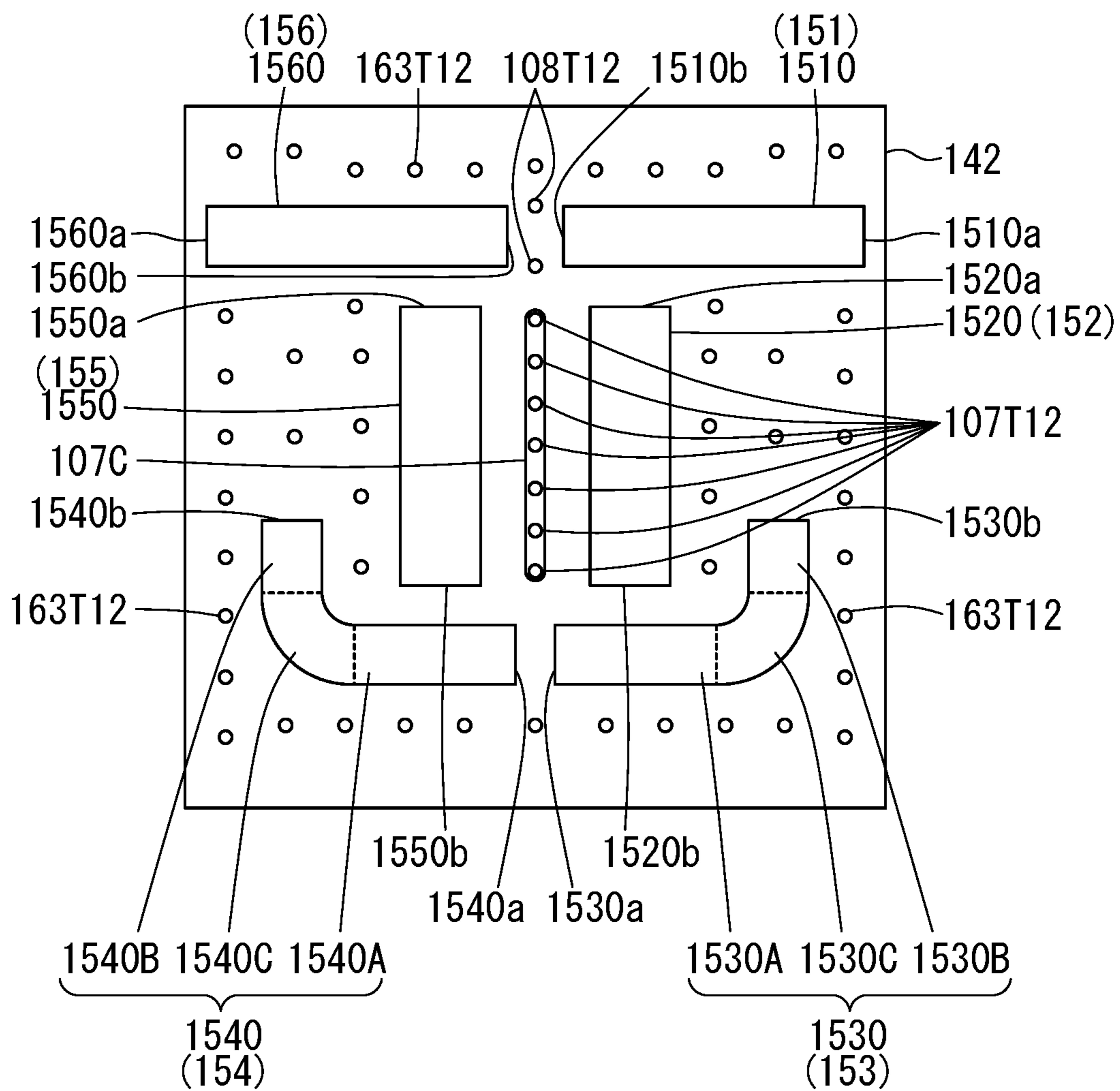


FIG. 22

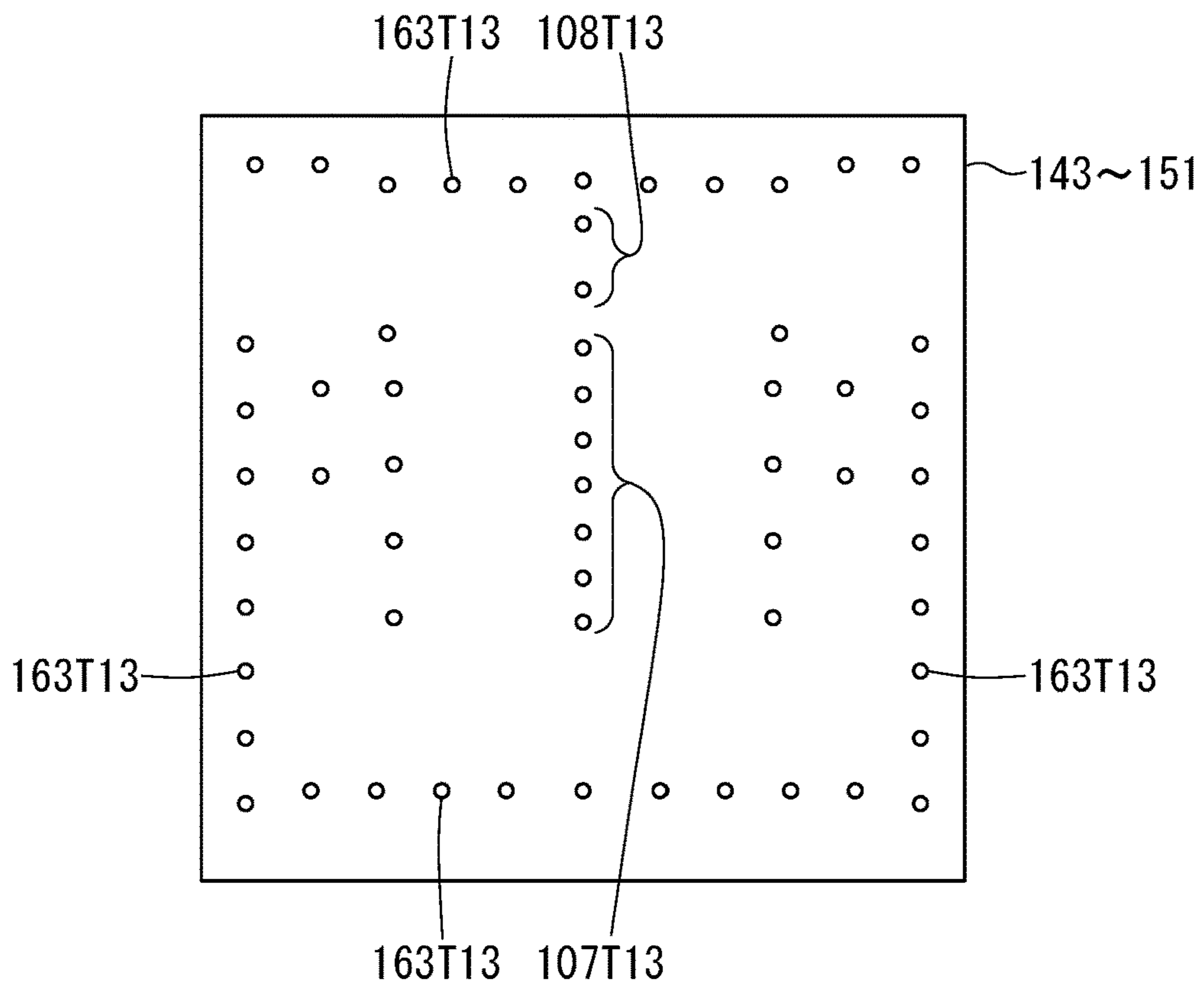


FIG. 23

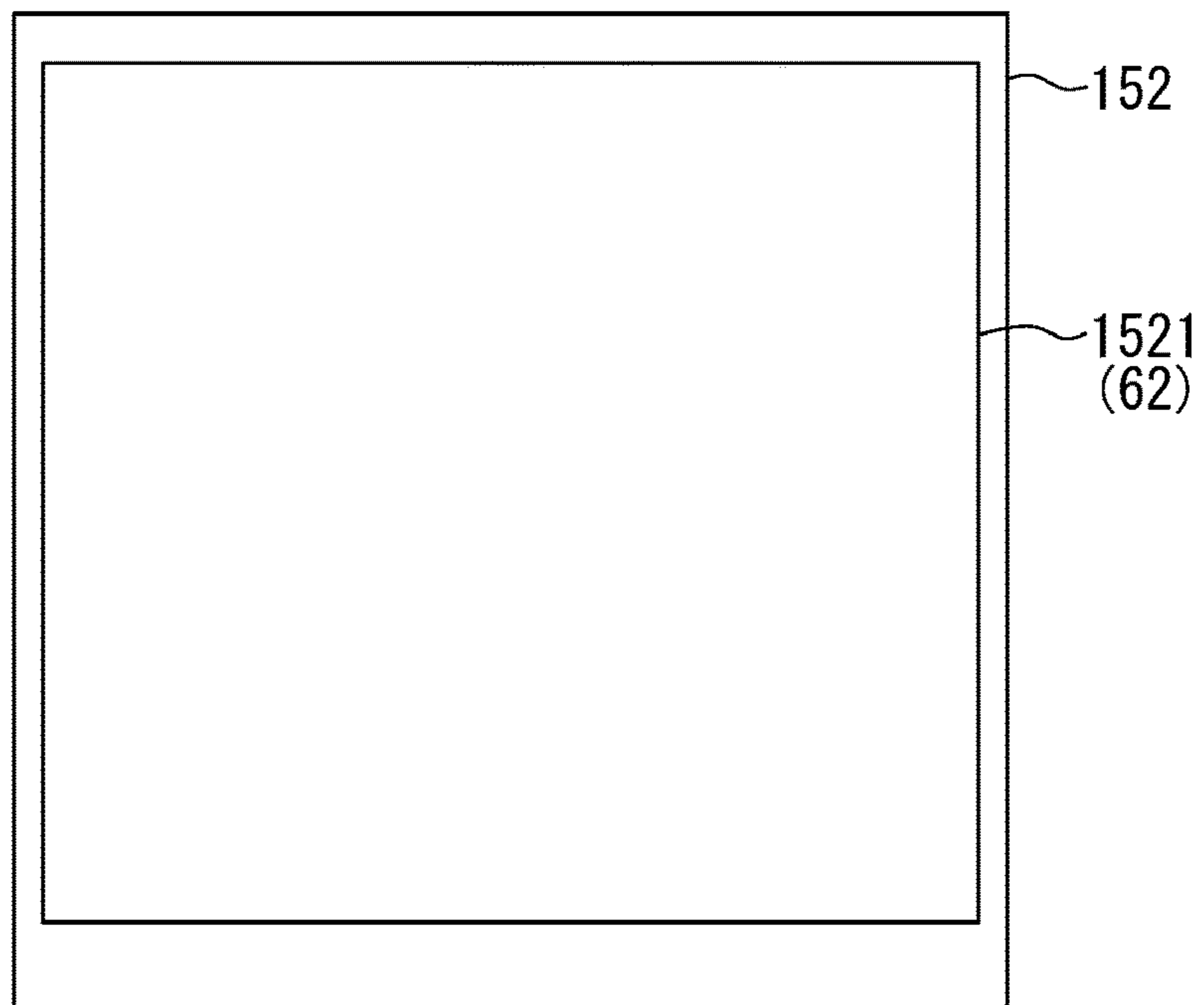


FIG. 24

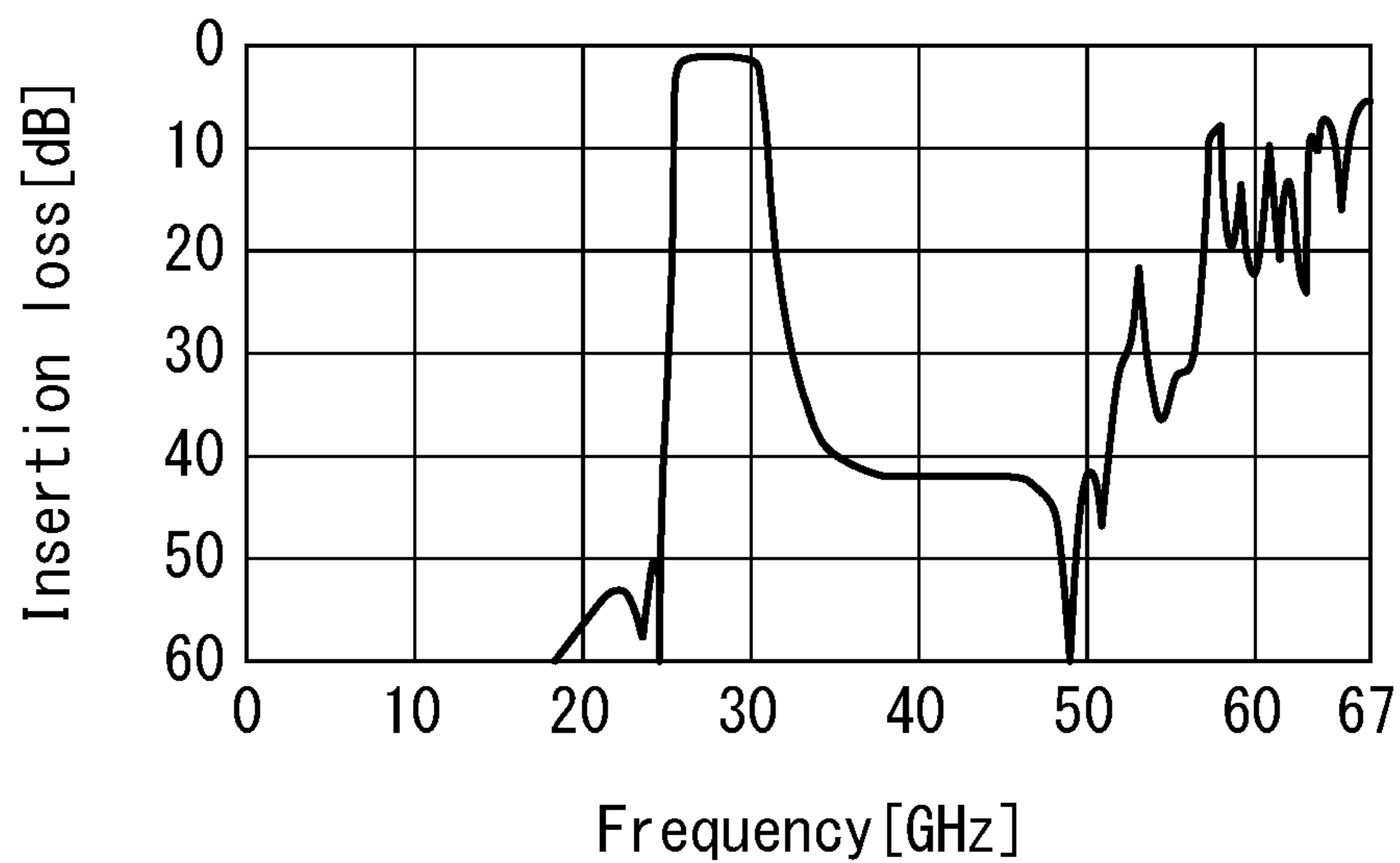


FIG. 25

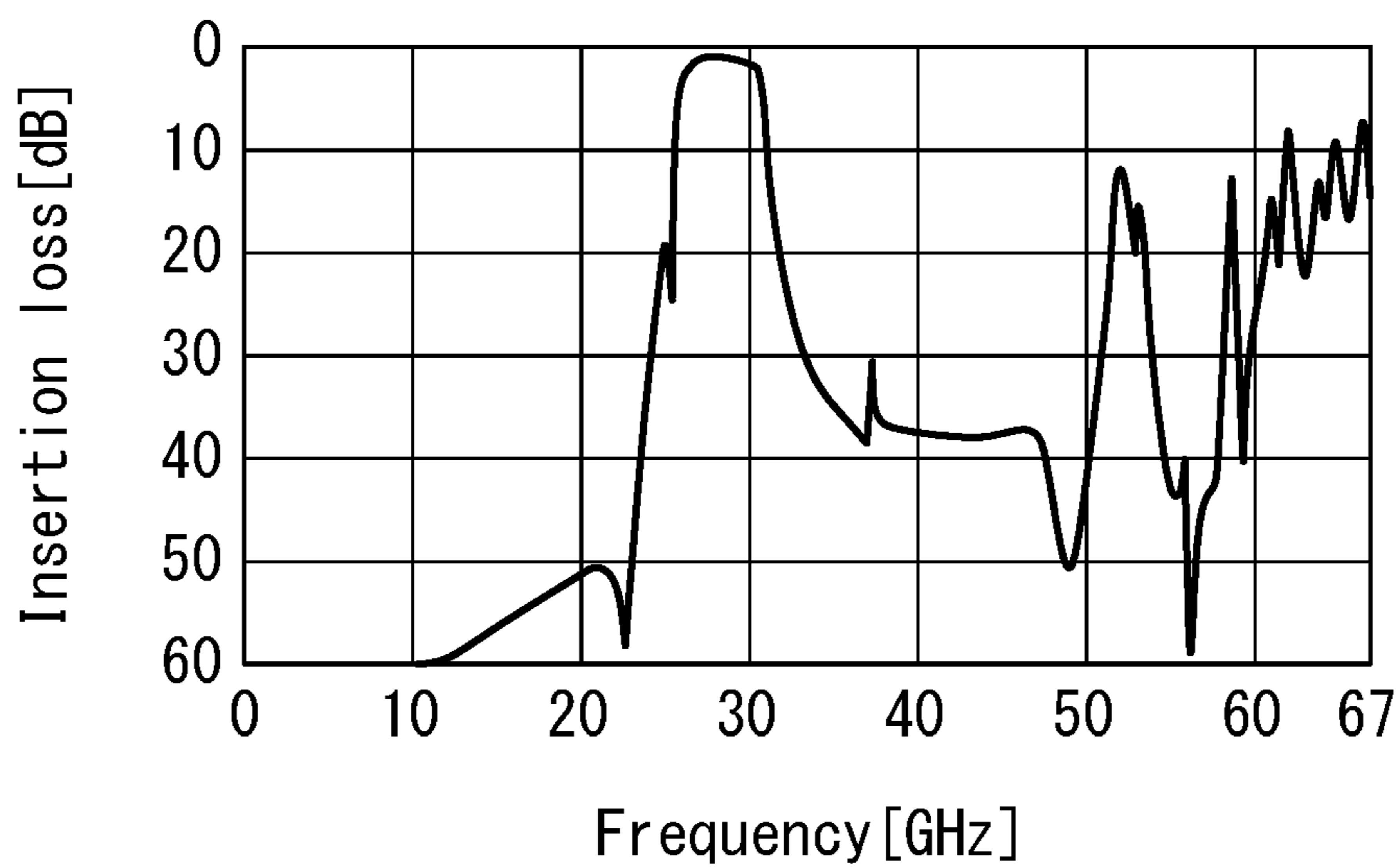


FIG. 26  
RELATED ART



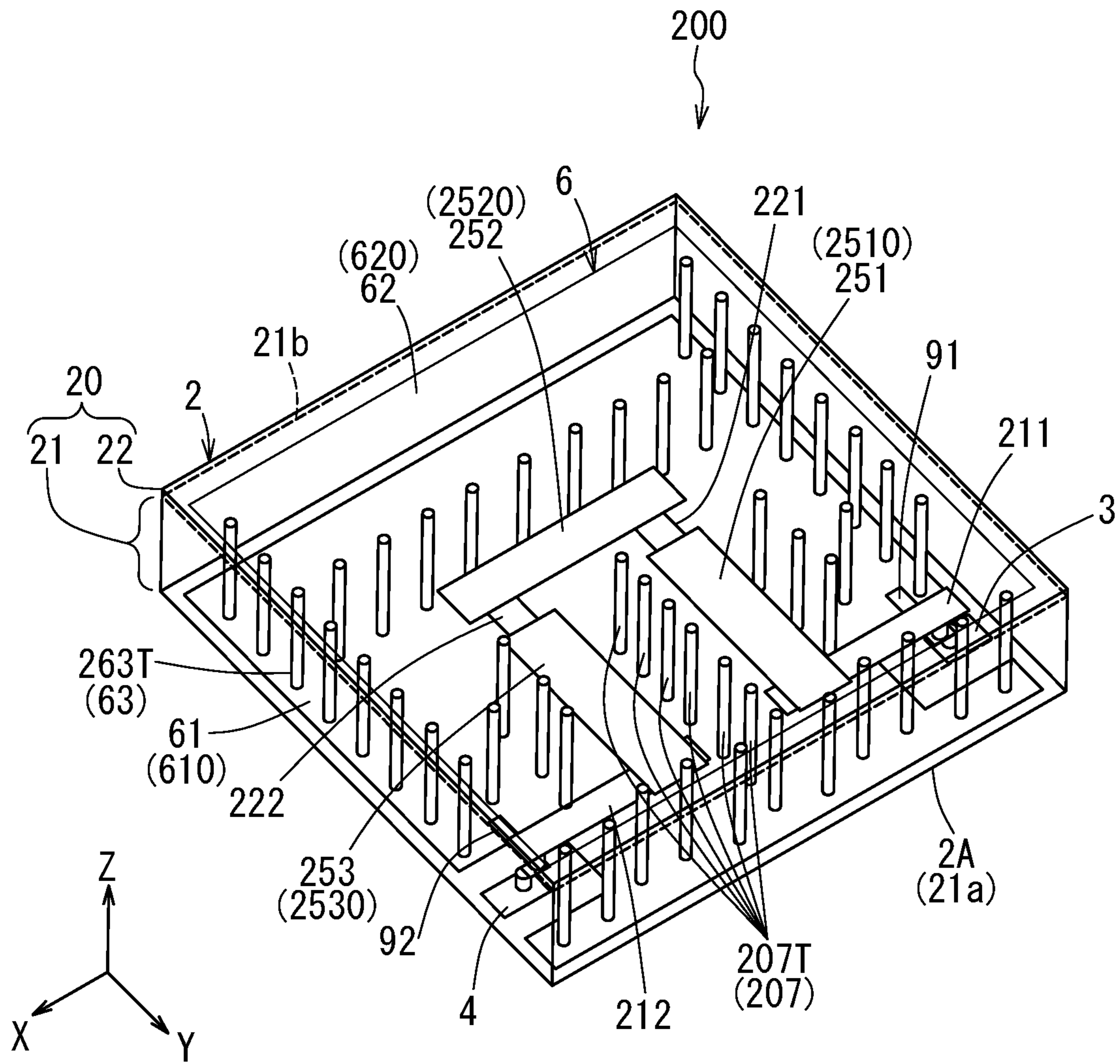


FIG. 27

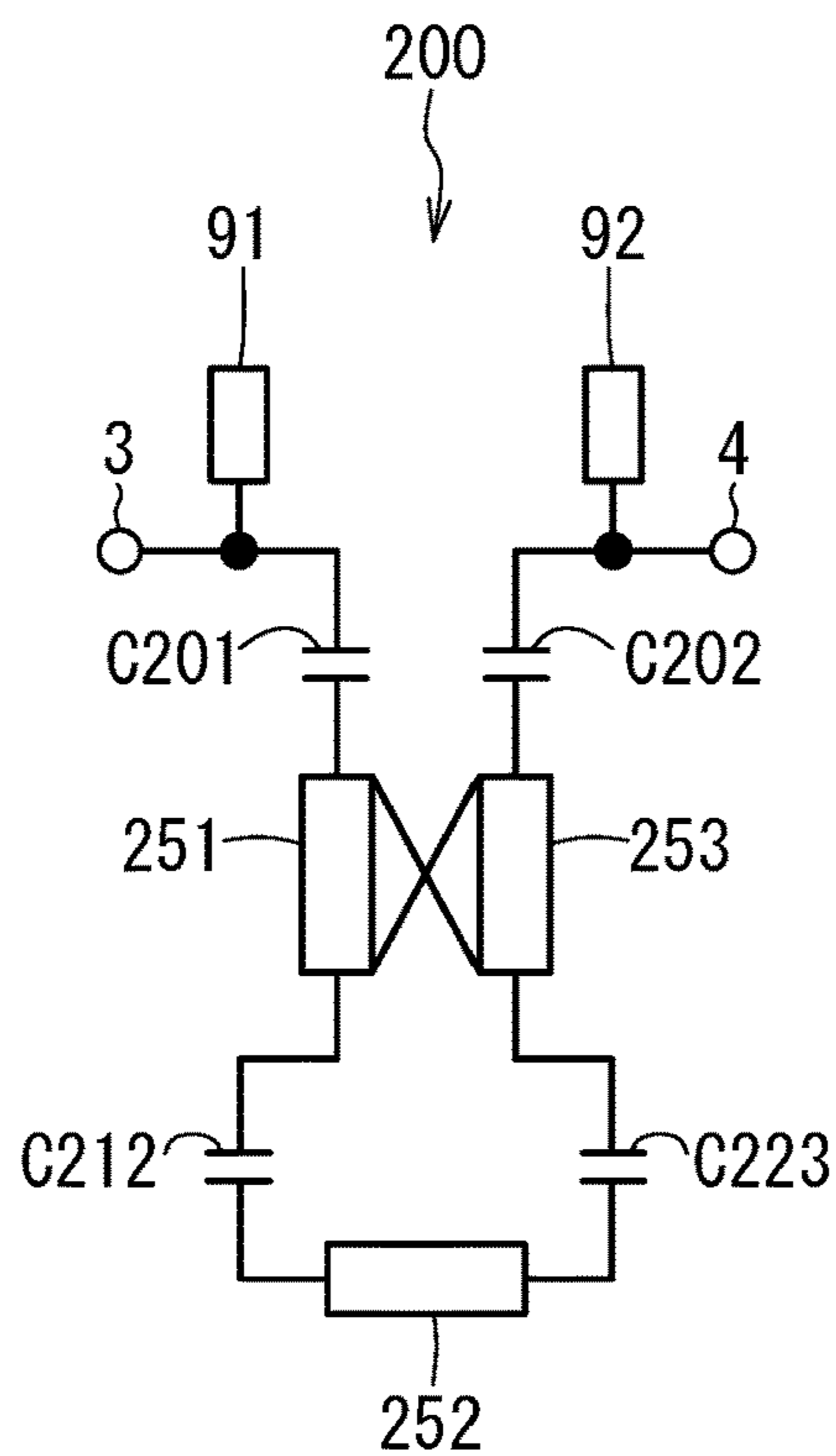


FIG. 28

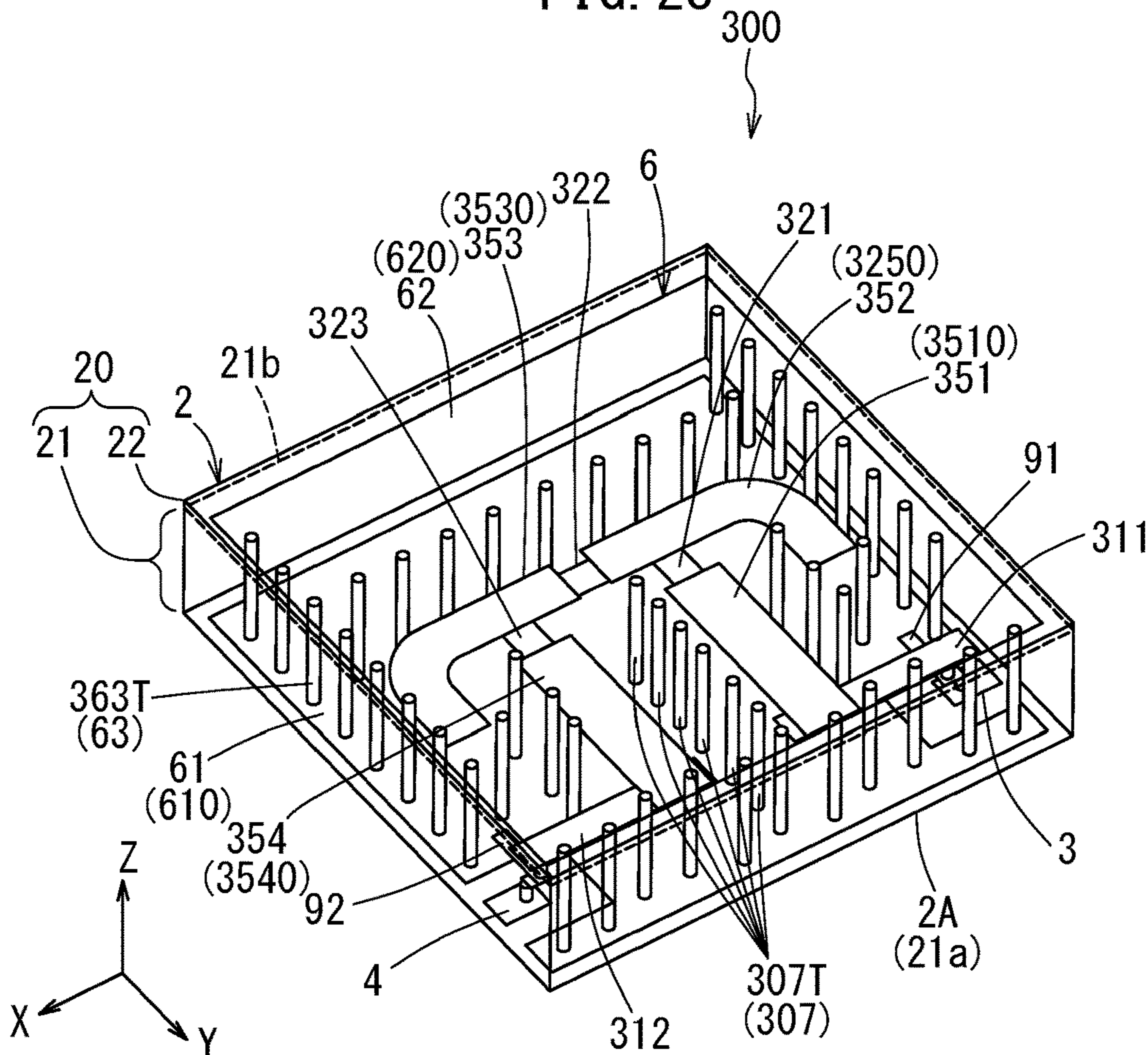


FIG. 29

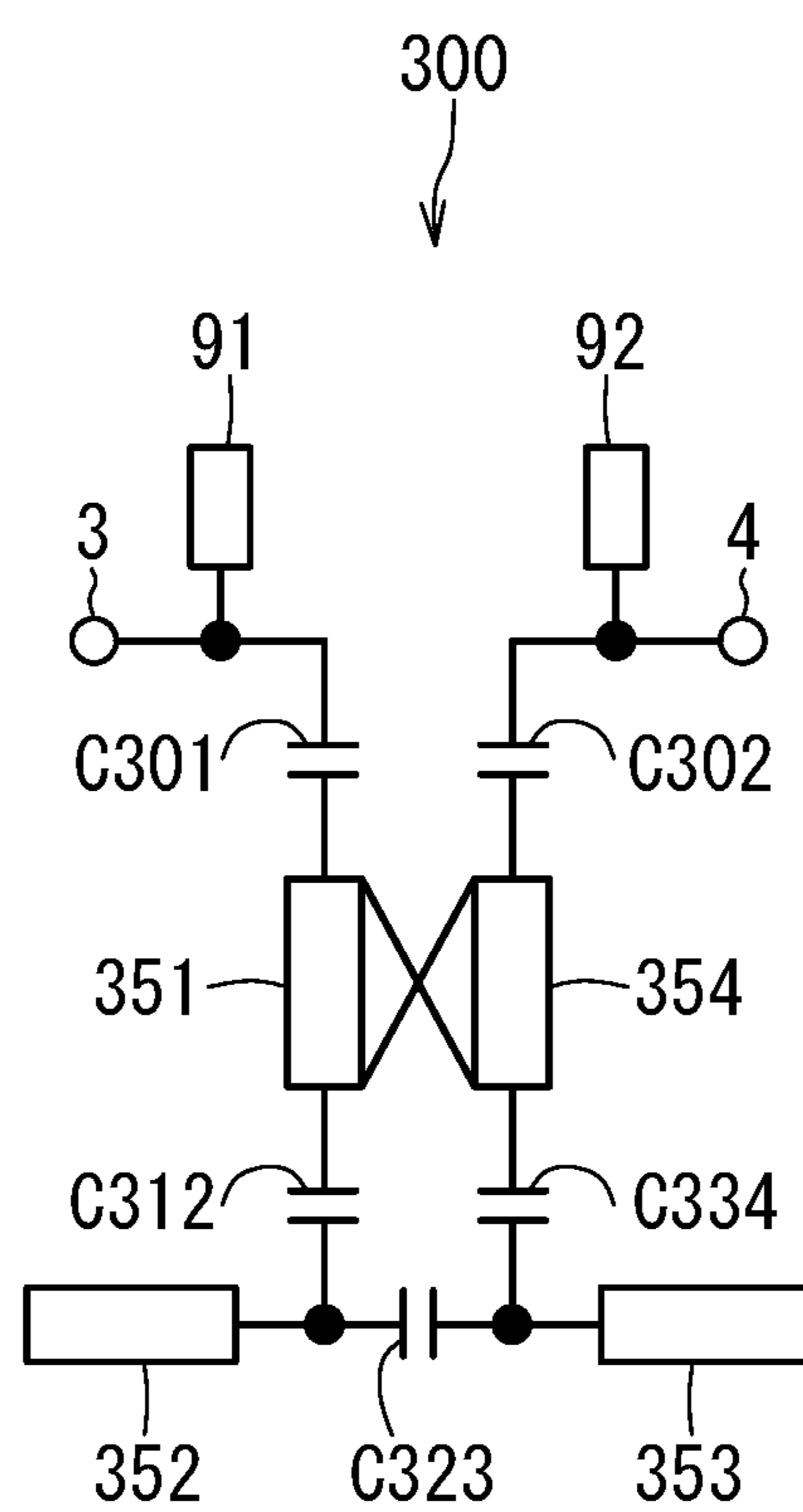


FIG. 30

## 1

## BAND-PASS FILTER

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention relates to a band-pass filter including a plurality of resonators and a shield.

## 2. Description of the Related Art

The standardization of fifth-generation mobile communication systems (hereinafter referred to as 5G) is currently ongoing. For 5G, the use of frequency bands of 10 GHz or higher, particularly a quasi-millimeter wave band of 10 to 30 GHz and a millimeter wave band of 30 to 300 GHz, is being studied to expand the frequency band.

One of electronic components used in a communication apparatus is a band-pass filter including a plurality of resonators. Each of the plurality of resonators includes, for example, a conductor portion that is long in one direction. To avoid electromagnetic radiation to the surroundings, some band-pass filters are configured so that the plurality of resonators are surrounded by a shield.

JP2006-311100A describes a chip-type multistage filter device usable in quasi-millimeter and millimeter wave bands. The chip-type multistage filter device includes a multilayer substrate, first and second surface ground electrodes, first and second internal ground electrodes, and first and second  $\lambda/2$  resonator electrodes. The multilayer substrate is formed by stacking a plurality of dielectric layers. The multilayer substrate has first and second main surfaces opposed to each other, and first to fourth side surfaces connecting the first and second main surfaces. The first side surface and the second side surface are opposed to each other. The first surface ground electrode is disposed on the first side surface. The second surface ground electrode is disposed on the second side surface. The first internal ground electrode is disposed on one of the dielectric layers of the multilayer substrate that is relatively close to the first main surface. The second internal ground electrode is disposed on another one of the dielectric layers of the multilayer substrate that is relatively close to the second main surface. The first and second  $\lambda/2$  resonator electrodes are disposed in an area surrounded by the first and second surface ground electrodes and the first and second internal ground electrodes.

The chip-type multistage filter device described in JP2006-311100A further includes a via hole conductor and a capacitance unit. The via hole conductor is formed to run through at least some of the dielectric layers so that the first and second internal ground electrodes are electrically connected to each other. The first and second  $\lambda/2$  resonator electrodes are opposed to each other with the via hole conductor interposed therebetween. The capacitance unit is disposed within the multilayer substrate to add a coupling capacitance to between the first and second  $\lambda/2$  resonator electrodes.

In a band-pass filter that is configured so that a plurality of resonators are surrounded by a shield, the shield and a dielectric material inside the shield constitute a structure similar to a waveguide, thereby generating at least one propagation mode for electromagnetic waves. Such a propagation mode for electromagnetic waves will hereinafter be referred to as a waveguide mode. In the band-pass filter, disadvantageously, the waveguide mode produces unwanted resonance having a resonance frequency in a frequency

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region above the passband, thus degrading the attenuation characteristic in the frequency region above the passband. For a band-pass filter that is designed to have a passband in the quasi-millimeter or millimeter wave band, the above-described problem is particularly noticeable because even the resonance frequency of a waveguide mode that is the lowest in resonance frequency (hereinafter, referred to as a lowest-order waveguide mode) is relatively close to the passband.

The resonance frequency of the lowest-order waveguide mode varies depending on the shape of the space defined by the shield. Typically, the larger the space, the lower the resonance frequency of the lowest-order waveguide mode.

JP 2006-311100A describes that resonance caused by outside shape can be reduced by the via hole conductor. The resonance caused by the outside shape corresponds to resonance caused by the above-described waveguide mode.

However, the filter device described in JP 2006-311100A has the following problem. In the filter device, the via hole conductor is disposed between the two  $\lambda/2$  resonator electrodes that are adjacent to each other in circuit configuration and are capacitively coupled to each other. Typically, in a band-pass filter in which two resonators adjacent to each other in circuit configuration are configured to be coupled to each other, strong coupling is required between such two resonators. The filter device described in JP 2006-311100A has the problem that the production of strong capacitive coupling between two  $\lambda/2$  resonator electrodes that are adjacent to each other in circuit configuration and the placement of the via hole conductor between such two  $\lambda/2$  resonator electrodes are difficult to achieve at the same time without a deterioration in the characteristics of the band-pass filter.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a band-pass filter including a plurality of resonators and a shield and having favorable characteristics.

A band-pass filter of the present invention includes: a main body formed of a dielectric; a first input/output port and a second input/output port integrated with the main body; three or more resonators; a shield; and a partition. The three or more resonators are provided within the main body, located between the first input/output port and the second input/output port in circuit configuration, and configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration. The shield is formed of a conductor and integrated with the main body. The partition is formed of a conductor, provided within the main body, and electrically connected to the shield.

The shield includes a first portion and a second portion spaced from each other in a first direction, and a connecting portion connecting the first and second portions. The first portion, the second portion and the connecting portion are arranged to surround the three or more resonators.

The three or more resonators include a first resonator and a second resonator that are configured to be magnetically coupled to each other although not adjacent to each other in circuit configuration. The first resonator includes a first resonator conductor portion formed of a conductor. The second resonator includes a second resonator conductor portion formed of a conductor. Each of the first and second resonator conductor portions extends in a direction intersecting the first direction.

The partition is in contact with the first portion and the second portion. At least part of the partition extends to pass between the first resonator conductor portion and the second resonator conductor portion.

In the band-pass filter of the present invention, the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration may be capacitive coupling.

In the band-pass filter of the present invention, each of the three or more resonators may be a resonator with open ends.

In the band-pass filter of the present invention, the partition may extend in the first direction and connect the first portion and the second portion via a shortest path.

In the band-pass filter of the present invention, the first resonator may be a resonator that is the closest to the first input/output port in circuit configuration, and the second resonator may be a resonator that is the closest to the second input/output port in circuit configuration. In this case, the three or more resonators may be five resonators.

In the band-pass filter of the present invention, the first resonator may be a resonator that is the second closest to the first input/output port in circuit configuration, and the second resonator may be a resonator that is the second closest to the second input/output port in circuit configuration. In this case, the three or more resonators may be six resonators.

The band-pass filter of the present invention may further include a notch filter section for attenuating a signal of a predetermined frequency higher than the passband.

In the band-pass filter of the present invention, the main body may include a multilayer stack composed of a plurality of dielectric layers stacked together in the first direction. In such a case, the multilayer stack may include a main portion composed of two or more dielectric layers stacked together, among the plurality of dielectric layers. The main portion has a first end face and a second end face located at opposite ends in the first direction. The first portion may be formed of a first conductor layer disposed on the first end face. The second portion may be formed of a second conductor layer disposed on the second end face. The partition may run through the two or more dielectric layers. The partition may include a plurality of first through hole lines each running through the two or more dielectric layers. Each of the plurality of first through hole lines may include two or more through holes connected in series. The connecting portion of the shield may include a plurality of second through hole lines each running through the two or more dielectric layers. Each of the plurality of second through hole lines may include two or more through holes connected in series.

In the band-pass filter of the present invention, when the main body includes the aforementioned multilayer stack, the first resonator conductor portion and the second resonator conductor portion may be located at the same position in the multilayer stack in the first direction.

In the band-pass filter of the present invention, the partition divides the space defined by the shield into a space in which the first resonator conductor portion is located and a space in which the second resonator conductor portion is located. The present invention thereby makes the resonance frequency of the lowest-order waveguide mode higher than in the case without the partition. Further, according to the present invention, magnetic coupling is established between the first resonator and the second resonator that are not adjacent to each other in circuit configuration. This enables creation of an attenuation pole in at least one of two frequency regions in a frequency response of insertion loss. One of the two frequency regions is a first passband-vicinity region, which is a frequency region close to the passband

and lower than the passband, and the other is a second passband-vicinity region, which is a frequency region close to the passband and higher than the passband. The present invention thus enables realization of a band-pass filter including a plurality of resonators and a shield and having favorable characteristics.

Other and further objects, features and advantages of the invention will appear more fully from the following description.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view illustrating the structure of a band-pass filter according to a first embodiment of the invention.

FIG. 2 is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the first embodiment of the invention.

FIG. 3 is an explanatory diagram illustrating a patterned surface of a first dielectric layer of a multilayer stack shown in FIG. 1.

FIG. 4 is an explanatory diagram illustrating a patterned surface of a second dielectric layer of the multilayer stack shown in FIG. 1.

FIG. 5 is an explanatory diagram illustrating a patterned surface of a third dielectric layer of the multilayer stack shown in FIG. 1.

FIG. 6 is an explanatory diagram illustrating a patterned surface of a fourth dielectric layer of the multilayer stack shown in FIG. 1.

FIG. 7 is an explanatory diagram illustrating a patterned surface of each of a fifth to a seventh dielectric layer of the multilayer stack shown in FIG. 1.

FIG. 8 is an explanatory diagram illustrating a patterned surface of an eighth dielectric layer of the multilayer stack shown in FIG. 1.

FIG. 9 is an explanatory diagram illustrating a patterned surface of a ninth dielectric layer of the multilayer stack shown in FIG. 1.

FIG. 10 is an explanatory diagram illustrating a patterned surface of each of a tenth to a seventeenth dielectric layer of the multilayer stack shown in FIG. 1.

FIG. 11 is an explanatory diagram illustrating a patterned surface of an eighteenth dielectric layer of the multilayer stack shown in FIG. 1.

FIG. 12 is a characteristic diagram illustrating an example of the frequency response of the insertion loss of the band-pass filter according to the first embodiment of the invention.

FIG. 13 is a characteristic diagram illustrating an example of the frequency response of the insertion loss of a band-pass filter of a first comparative example.

FIG. 14 is a perspective view illustrating the structure of a band-pass filter according to a second embodiment of the invention.

FIG. 15 is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the second embodiment of the invention.

FIG. 16 is an explanatory diagram illustrating a patterned surface of a first dielectric layer of the multilayer stack shown in FIG. 14.

FIG. 17 is an explanatory diagram illustrating a patterned surface of each of a second and a third dielectric layer of the multilayer stack shown in FIG. 14.

FIG. 18 is an explanatory diagram illustrating a patterned surface of a fourth dielectric layer of the multilayer stack shown in FIG. 14.

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FIG. 19 is an explanatory diagram illustrating a patterned surface of each of a fifth to a ninth dielectric layer of the multilayer stack shown in FIG. 14.

FIG. 20 is an explanatory diagram illustrating a patterned surface of a tenth dielectric layer of the multilayer stack shown in FIG. 14.

FIG. 21 is an explanatory diagram illustrating a patterned surface of an eleventh dielectric layer of the multilayer stack shown in FIG. 14.

FIG. 22 is an explanatory diagram illustrating a patterned surface of a twelfth dielectric layer of the multilayer stack shown in FIG. 14.

FIG. 23 is an explanatory diagram illustrating a patterned surface of each of a thirteenth to a twenty-first dielectric layer of the multilayer stack shown in FIG. 14.

FIG. 24 is an explanatory diagram illustrating a patterned surface of a twenty-second dielectric layer of the multilayer stack shown in FIG. 14.

FIG. 25 is a characteristic diagram illustrating an example of the frequency response of the insertion loss of the band-pass filter according to the second embodiment of the invention.

FIG. 26 is a characteristic diagram illustrating an example of the frequency response of the insertion loss of a band-pass filter of a second comparative example.

FIG. 27 is a perspective view illustrating the structure of a band-pass filter according to a third embodiment of the invention.

FIG. 28 is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the third embodiment of the invention.

FIG. 29 is a perspective view illustrating the structure of a band-pass filter according to a fourth embodiment of the invention.

FIG. 30 is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the fourth embodiment of the invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

### First Embodiment

Preferred embodiments of the present invention will now be described in detail with reference to the drawings. First, reference is made to FIG. 1 and FIG. 2 to describe the configuration of a band-pass filter according to a first embodiment of the invention. FIG. 1 is a perspective view illustrating the structure of the band-pass filter according to the present embodiment. FIG. 2 is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the present embodiment.

As shown in FIG. 1, the band-pass filter 1 according to the present embodiment includes: a main body 2 formed of a dielectric; a first input/output port 3 and a second input/output port 4 integrated with the main body 2; three or more resonators provided within the main body 2; a shield 6; a first partition 7; and a second partition 8. The shield 6 is formed of a conductor and integrated with the main body 2. The shield 6 is connected to the ground. The shield 6 has the function of preventing electromagnetic radiation to the surroundings of the band-pass filter 1. Each of the first partition 7 and the second partition 8 is formed of a conductor, provided within the main body 2 and electrically connected to the shield 6. The first partition 7 corresponds to the partition in the present invention.

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The main body 2 includes a multilayer stack 20 composed of a plurality of dielectric layers stacked together. Here, X, Y and Z directions are defined as shown in FIG. 1. The X, Y and Z directions are orthogonal to one another. In the present embodiment, the direction in which the plurality of dielectric layers are stacked is the Z direction (the upward direction in FIG. 1). The Z direction corresponds to the first direction in the present invention.

The main body 2 is shaped like a rectangular solid. The main body 2 has a first end face 2A and a second end face 2B located at opposite ends in the Z direction of the main body 2, and further has four side surfaces 2C, 2D, 2E and 2F connecting the first end face 2A and the second end face 2B. The first end face 2A is also the bottom surface of the main body 2. The second end face 2B is also the top surface of the main body 2. The side surfaces 2C and 2D are located at opposite ends in the Y direction of the main body 2. The side surfaces 2E and 2F are located at opposite ends in the X direction of the main body 2.

The three or more resonators are located between the first input/output port 3 and the second input/output port 4 in circuit configuration. The three or more resonators are configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration. As used herein, the phrase "in circuit configuration" is to describe layout in a circuit diagram, not in a physical configuration. Among the three or more resonators, a resonator that is the n-th closest to the first input/output port 3 in circuit configuration may also be referred to as the n-th stage resonator.

In the present embodiment, as shown in FIG. 2, the three or more resonators are specifically five resonators 51, 52, 53, 54 and 55. The five resonators 51, 52, 53, 54 and 55 are arranged in this order, from closest to farthest, from the first input/output port 3 in circuit configuration. The resonators 51 to 55 are configured so that the resonators 51 and 52 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators 52 and 53 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators 53 and 54 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, and the resonators 54 and 55 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other. In the present embodiment, the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is specifically capacitive coupling. In the present embodiment, each of the resonators 51 to 55 is a resonator with open ends, and also a half-wave resonator.

The band-pass filter 1 includes a capacitor C12 for establishing capacitive coupling between the resonators 51 and 52, a capacitor C23 for establishing capacitive coupling between the resonators 52 and 53, a capacitor C34 for establishing capacitive coupling between the resonators 53 and 54, and a capacitor C45 for establishing capacitive coupling between the resonators 54 and 55.

In a band-pass filter including three or more resonators configured so that every two of the resonators adjacent to each other in circuit configuration are coupled to each other, electromagnetic coupling may be established between two resonators that are not adjacent to each other in circuit configuration. Such electromagnetic coupling between non-adjacent resonators will be referred to as cross coupling. As will be described in detail below, the band-pass filter 1 according to the present embodiment has two cross couplings.

In the present embodiment, among the five resonators **51** to **55**, the resonator **51**, which is the closest to the first input/output port **3** in circuit configuration, and the resonator **55**, which is the closest to the second input/output port **4** in circuit configuration, are magnetically coupled to each other although they are not adjacent to each other in circuit configuration. The resonator **51** corresponds to the first resonator in the present invention. The resonator **55** corresponds to the second resonator in the present invention.

Further, in the present embodiment, among the five resonators **51** to **55**, the resonator **52**, which is the second closest to the first input/output port **3** in circuit configuration, and the resonator **54**, which is the second closest to the second input/output port **4** in circuit configuration, are capacitively coupled to each other although they are not adjacent to each other in circuit configuration. In FIG. 2, the capacitor symbol **C24** represents the capacitive coupling between the resonators **52** and **54**.

The band-pass filter **1** further includes a capacitor **C1** provided between the first input/output port **3** and the resonator **51**, and a capacitor **C2** provided between the second input/output port **4** and the resonator **55**.

The band-pass filter **1** further includes a notch filter section for attenuating a signal of a predetermined frequency (hereinafter referred to as notch frequency) higher than the passband. The notch filter section includes two lines **91** and **92** each formed of a conductor. Each of the lines **91** and **92** has a first end and a second end opposite to each other. The first end of the line **91** is connected to the first input/output port **3**, and the second end of the line **91** is open. The first end of the line **92** is connected to the second input/output port **4**, and the second end of the line **92** is open. Each of the lines **91** and **92** has a length of one quarter or nearly one quarter the wavelength corresponding to the notch frequency. Each of the lines **91** and **92** is a quarter-wave resonator that resonates at the notch frequency. The notch frequency is, for example, twice the center frequency of the passband of the band-pass filter **1**.

The shield **6** includes a first portion **61** and a second portion **62** spaced from each other in the first direction, i.e., the Z direction, and a connecting portion **63** connecting the first portion **61** and the second portion **62**. The first portion **61**, the second portion **62** and the connecting portion **63** are arranged to surround the five resonators **51** to **55**.

The multilayer stack **20** includes a main portion **21** and a coating portion **22**. The main portion **21** is composed of two or more dielectric layers stacked together, among the plurality of dielectric layers constituting the multilayer stack **20**. The coating portion **22** is composed of one or more dielectric layers other than the two or more dielectric layers constituting the main portion **21**, among the plurality of dielectric layers constituting the multilayer stack **20**. The main portion **21** has a first end face **21a** and a second end face **21b** located at opposite ends in the direction in which the two or more dielectric layers are stacked. The coating portion **22** covers the second end face **21b**. The first end face **21a** of the main portion **21** coincides with the first end face **2A** of the main body **2**. The second end face **21b** of the main portion **21** is located within the main body **2**.

The first portion **61** is formed of a first conductor layer **313** disposed on the first end face **21a**. The second portion **62** is formed of a second conductor layer **481** disposed on the second end face **21b**. The second portion **62** is interposed between the main portion **21** and the coating portion **22**.

The resonator **51** includes a resonator conductor portion **510** formed of a conductor. The resonator **52** includes a resonator conductor portion **520** formed of a conductor. The

resonator **53** includes a resonator conductor portion **530** formed of a conductor. The resonator **54** includes a resonator conductor portion **540** formed of a conductor. The resonator **55** includes a resonator conductor portion **550** formed of a conductor. The resonator conductor portion **510** corresponds to the first resonator conductor portion in the present invention. The resonator conductor portion **550** corresponds to the second resonator conductor portion in the present invention.

Each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** extends in a direction intersecting the first direction or the Z direction. In the present embodiment, specifically, each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** extends in a direction orthogonal to the first direction or the Z direction.

Each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** has a first end and a second end opposite to each other. As mentioned above, each of the resonators **51** to **55** is a resonator with open ends. Thus, both of the first and second ends of each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** are open. Each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** has a length of one half or nearly one half the wavelength corresponding to the center frequency of the passband of the band-pass filter **1**.

The partition **7** is in contact with the first portion **61** and the second portion **62**. At least part of the partition **7** extends to pass between the resonator conductor portion **510** and the resonator conductor portion **550**. In the present embodiment, specifically, the first partition **7** extends in the first direction, i.e., the Z direction. The first partition **7** connects the first portion **61** and the second portion **62** via the shortest path. To be more specific, the length of the first partition **7** in the Z direction is equal to the distance between the first portion **61** and the second portion **62**.

The first partition **7** runs through the two or more dielectric layers constituting the main portion **21**. In the present embodiment, the first partition **7** includes a plurality of through hole lines **7T** each running through the two or more dielectric layers constituting the main portion **21**. The plurality of through hole lines **7T** correspond to the plurality of first through hole lines in the present invention. In FIG. 1, each through hole line **7T** is represented by a circular column. Each of the through hole lines **7T** includes two or more through holes connected in series. Each of the through hole lines **7T** extends in the Z direction. The through hole lines **7T** are arranged to be adjacent to each other in the Y direction. In the present embodiment, the number of the through hole lines **7T** is five.

The second partition **8** extends to pass through the area surrounded by the resonator conductor portions **520**, **530** and **540**, and is in contact with the first portion **61** and the second portion **62**. In the present embodiment, specifically, the second partition **8** extends in the first direction, i.e., the Z direction. The second partition **8** connects the first portion **61** and the second portion **62** via the shortest path. To be more specific, the length of the second partition **8** in the Z direction is equal to the distance between the first portion **61** and the second portion **62**.

The second partition **8** runs through the two or more dielectric layers constituting the main portion **21**. In the present embodiment, the second partition **8** includes a plurality of through hole lines **8T** each running through the two or more dielectric layers constituting the main portion **21**. In FIG. 1, each through hole line **8T** is represented by a circular column. Each of the through hole lines **8T** includes two or more through holes connected in series. Each of the through hole lines **8T** extends in the Z direction. The through hole

lines 8T are arranged to be adjacent to each other in the X direction. In the present embodiment, the number of the through hole lines 8T is five.

The connecting portion 63 of the shield 6 includes a plurality of through hole lines 63T each running through the two or more dielectric layers constituting the main portion 21. The plurality of through hole lines 63T correspond to the second through hole lines in the present invention. In FIG. 1, each through hole line 63T is represented by a circular column. All the through hole lines represented by circular columns in FIG. 1, except the five through hole lines 7T and the five through hole lines 8T, are the through hole lines 63T. Each of the through hole lines 63T includes two or more through holes connected in series. Each of the through hole lines 63T extends in the Z direction.

Reference is now made to FIG. 3 to FIG. 11 to describe an example of the dielectric layers constituting the multilayer stack 20 and the configuration of a plurality of conductor layers formed on the dielectric layers and a plurality of through holes formed in the dielectric layers. In this example, the multilayer stack 20 includes eighteen dielectric layers stacked together. The eighteen dielectric layers will be referred to as the first to eighteenth dielectric layers in the order from bottom to top. The first to eighteenth dielectric layers are denoted by reference numerals 31 to 48, respectively. The main portion 21 is composed of the first to seventeenth dielectric layers 31 to 47. The coating portion 22 is composed of the eighteenth dielectric layer 48. In FIG. 3 to FIG. 10, each circle represents a through hole.

FIG. 3 illustrates a patterned surface of the first dielectric layer 31. On the patterned surface of the first dielectric layer 31, there are formed a conductor layer 311 forming the first input/output port 3, a conductor layer 312 forming the second input/output port 4, and the first conductor layer 313 forming the first portion 61 of the shield 6.

Further, a through hole 31T1 connected to the conductor layer 311, and a through hole 31T2 connected to the conductor layer 312 are formed in the dielectric layer 31.

Further formed in the dielectric layer 31 are five through holes 7T1 constituting respective portions of the five through hole lines 7T, five through holes 8T1 constituting respective portions of the five through hole lines 8T, and a plurality of through holes 63T1 constituting respective portions of the plurality of through hole lines 63T. All the through holes represented by circles in FIG. 3, except the through holes 31T1, 31T2, 7T1 and 8T1, are the through holes 63T1. The through holes 7T1, 8T1 and 63T1 are connected to the first conductor layer 313.

FIG. 4 illustrates a patterned surface of the second dielectric layer 32. Conductor layers 321 and 322 are formed on the patterned surface of the dielectric layer 32. The through holes 31T1 and 31T2 shown in FIG. 3 are connected to the conductor layers 321 and 322, respectively.

In the dielectric layer 32, there are formed a through hole 32T1 connected to the conductor layer 321, and a through hole 32T2 connected to the conductor layer 322.

Further formed in the dielectric layer 32 are five through holes 7T2 constituting respective portions of the five through hole lines 7T. The five through holes 7T1 shown in FIG. 3 are connected to the five through holes 7T2, respectively.

Further formed in the dielectric layer 32 are five through holes 8T2 constituting respective portions of the five through hole lines 8T. The five through holes 8T1 shown in FIG. 3 are connected to the five through holes 8T2, respectively.

Further formed in the dielectric layer 32 are a plurality of through holes 63T2 constituting respective portions of the plurality of through hole lines 63T. All the through holes represented by circles in FIG. 4, except the through holes 32T1, 32T2, 7T2 and 8T2, are the through holes 63T2. The plurality of through holes 63T1 shown in FIG. 3 are connected to the plurality of through holes 63T2, respectively.

FIG. 5 illustrates a patterned surface of the third dielectric layer 33. Through holes 33T1 and 33T2 are formed in the dielectric layer 33. The through holes 32T1 and 32T2 shown in FIG. 4 are connected to the through holes 33T1 and 33T2, respectively.

Further formed in the dielectric layer 33 are five through holes 7T3 constituting respective portions of the five through hole lines 7T. The five through holes 7T2 shown in FIG. 4 are connected to the five through holes 7T3, respectively.

Further formed in the dielectric layer 33 are five through holes 8T3 constituting respective portions of the five through hole lines 8T. The five through holes 8T2 shown in FIG. 4 are connected to the five through holes 8T3, respectively.

Further formed in the dielectric layer 33 are a plurality of through holes 63T3 constituting respective portions of the plurality of through hole lines 63T. All the through holes represented by circles in FIG. 5, except the through holes 33T1, 33T2, 7T3 and 8T3, are the through holes 63T3. The plurality of through holes 63T2 shown in FIG. 4 are connected to the plurality of through holes 63T3, respectively.

FIG. 6 illustrates a patterned surface of the fourth dielectric layer 34. On the patterned surface of the dielectric layer 34, there are formed a conductor layer 341 forming the line 91, and a conductor layer 342 forming the line 92. Each of the conductor layers 341 and 342 has a first end and a second end opposite to each other. The through hole 33T1 shown in FIG. 5 is connected to a portion of the conductor layer 341 near the first end thereof. The through hole 33T2 shown in FIG. 5 is connected to a portion of the conductor layer 342 near the first end thereof. A portion of the conductor layer 341 near the second end thereof and a portion of the conductor layer 342 near the second end thereof are opposed to the conductor layer 313 shown in FIG. 3 with the dielectric layers 31, 32 and 33 interposed between the conductor layer 313 and each of the aforementioned portions of the conductor layers 341 and 342.

Further formed in the dielectric layer 34 are a through hole 34T1 connected to the portion of the conductor layer 341 near the first end thereof, and a through hole 34T2 connected to the portion of the conductor layer 342 near the first end thereof.

Further formed in the dielectric layer 34 are five through holes 7T4 constituting respective portions of the five through hole lines 7T. The five through holes 7T3 shown in FIG. 5 are connected to the five through holes 7T4, respectively.

Further formed in the dielectric layer 34 are five through holes 8T4 constituting respective portions of the five through hole lines 8T. The five through holes 8T3 shown in FIG. 5 are connected to the five through holes 8T4, respectively.

Further formed in the dielectric layer 34 are a plurality of through holes 63T4 constituting respective portions of the plurality of through hole lines 63T. All the through holes represented by circles in FIG. 6, except the through holes 34T1, 34T2, 7T4 and 8T4, are the through holes 63T4. The plurality of through holes 63T3 shown in FIG. 5 are connected to the plurality of through holes 63T4, respectively.



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FIG. 7 illustrates a patterned surface of each of the fifth to seventh dielectric layers 35 to 37. Through holes 35T1 and 35T2 are formed in each of the dielectric layers 35 to 37. The through holes 34T1 and 34T2 shown in FIG. 6 are respectively connected to the through holes 35T1 and 35T2 formed in the fifth dielectric layer 35.

In each of the dielectric layers 35 to 37, there are further formed five through holes 7T5 constituting respective portions of the five through hole lines 7T. The five through holes 7T4 shown in FIG. 6 are respectively connected to the five through holes 7T5 formed in the fifth dielectric layer 35.

In each of the dielectric layers 35 to 37, there are further formed five through holes 8T5 constituting respective portions of the five through hole lines 8T. The five through holes 8T4 shown in FIG. 6 are respectively connected to the five through holes 8T5 formed in the fifth dielectric layer 35.

Further, a plurality of through holes 63T5 constituting respective portions of the plurality of through hole lines 63T are formed in each of the dielectric layers 35 to 37. All the through holes represented by circles in FIG. 7, except the through holes 35T1, 35T2, 7T5 and 8T5, are the through holes 63T5. The plurality of through holes 63T4 shown in FIG. 6 are respectively connected to the plurality of through holes 63T5 formed in the fifth dielectric layer 35.

In the dielectric layers 35 to 37, every vertically adjacent through holes denoted by the same reference signs are connected to each other.

FIG. 8 illustrates a patterned surface of the eighth dielectric layer 38. On the patterned surface of the dielectric layer 38, there are formed a conductor layer 381 for forming the capacitor C1 shown in FIG. 2 and a conductor layer 382 for forming the capacitor C2 shown in FIG. 2. The through hole 35T1 formed in the seventh dielectric layer 37 is connected to the conductor layer 381. The through hole 35T2 formed in the seventh dielectric layer 37 is connected to the conductor layer 382.

On the patterned surface of the dielectric layer 38, there are further formed conductor layers 383, 384, 385 and 386 for forming the capacitors C12, C23, C34 and C45 shown in FIG. 2, respectively.

Further, five through holes 7T8 constituting respective portions of the five through hole lines 7T are formed in the dielectric layer 38. The five through holes 7T5 formed in the seventh dielectric layer 37 are connected to the five through holes 7T8, respectively.

Further formed in the dielectric layer 38 are five through holes 8T8 constituting respective portions of the five through hole lines 8T. The five through holes 8T5 formed in the seventh dielectric layer 37 are connected to the five through holes 8T8, respectively.

Further formed in the dielectric layer 38 are a plurality of through holes 63T8 constituting respective portions of the plurality of through hole lines 63T. All the through holes represented by circles in FIG. 8, except the through holes 7T8 and 8T8, are the through holes 63T8. The plurality of through holes 63T5 formed in the seventh dielectric layer 37 are connected to the plurality of through holes 63T8, respectively.

FIG. 9 illustrates a patterned surface of the ninth dielectric layer 39. The resonator conductor portions 510, 520, 530, 540 and 550 are formed on the patterned surface of the dielectric layer 39.

The resonator conductor portion 510 has a first end 510a and a second end 510b opposite to each other. The resonator conductor portion 520 has a first end 520a and a second end 520b opposite to each other. The resonator conductor portion 530 has a first end 530a and a second end 530b opposite to

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each other. The resonator conductor portion 540 has a first end 540a and a second end 540b opposite to each other. The resonator conductor portion 550 has a first end 550a and a second end 550b opposite to each other.

The resonator conductor portion 510 includes a first portion 510A, a second portion 510B and a third portion 510C. The first portion 510A includes the first end 510a, and the second portion 510B includes the second end 510b. The first portion 510A extends in the X direction, and the second portion 510B extends in the Y direction. The third portion 510C connects an end of the first portion 510A opposite from the first end 510a and an end of the second portion 510B opposite from the second end 510b. In FIG. 9, the boundary between the first portion 510A and the third portion 510C and the boundary between the second portion 510B and the third portion 510C are shown by broken lines. The first portion 510A is closer to the first input/output port 3 than the second portion 510B in circuit configuration.

The resonator conductor portion 550 includes a first portion 550A, a second portion 550B and a third portion 550C. The first portion 550A includes the first end 550a, and the second portion 550B includes the second end 550b. The first portion 550A extends in the X direction, and the second portion 550B extends in the Y direction. The third portion 550C connects an end of the first portion 550A opposite from the first end 550a and an end of the second portion 550B opposite from the second end 550b. In FIG. 9, the boundary between the first portion 550A and the third portion 550C and the boundary between the second portion 550B and the third portion 550C are shown by broken lines. The first portion 550A is closer to the second input/output port 4 than the second portion 550B in circuit configuration.

The second portion 510B of the resonator conductor portion 510 and the second portion 550B of the resonator conductor portion 550 are at a predetermined distance from each other and adjacent to each other in the X direction. The distance between the second portion 510B and the second portion 550B is smaller than the length of each of the resonator conductor portions 510 and 550.

The resonator conductor portion 520 includes a first portion 520A, a second portion 520B and a third portion 520C. The first portion 520A includes the first end 520a, and the second portion 520B includes the second end 520b. The first portion 520A extends in the X direction, and the second portion 520B extends in the Y direction. The third portion 520C connects an end of the first portion 520A opposite from the first end 520a and an end of the second portion 520B opposite from the second end 520b. In FIG. 9, the boundary between the first portion 520A and the third portion 520C and the boundary between the second portion 520B and the third portion 520C are shown by broken lines. The first end 520a is located near the second end 510b of the resonator conductor portion 510.

The resonator conductor portion 540 includes a first portion 540A, a second portion 540B and a third portion 540C. The first portion 540A includes the first end 540a, and the second portion 540B includes the second end 540b. The first portion 540A extends in the X direction, and the second portion 540B extends in the Y direction. The third portion 540C connects an end of the first portion 540A opposite from the first end 540a and an end of the second portion 540B opposite from the second end 540b. In FIG. 9, the boundary between the first portion 540A and the third portion 540C and the boundary between the second portion 540B and the third portion 540C are shown by broken lines. The first end 540a is located near the second end 550b of the resonator conductor portion 550.

The first end **520a** of the resonator conductor portion **520** and the first end **540a** of the resonator conductor portion **540** are at a predetermined distance from each other and adjacent to each other. The distance between the first end **520a** and the first end **540a** is sufficiently smaller than the length of each of the resonator conductor portions **520** and **540**.

The resonator conductor portion **530** extends in the X direction. The first end **530a** of the resonator conductor portion **530** is located near the second end **520b** of the resonator conductor portion **520**. The second end **530b** of the resonator conductor portion **530** is located near the second end **540b** of the resonator conductor portion **540**. Further, five through holes **7T9** constituting respective portions of the five through hole lines **7T** are formed in the dielectric layer **39**. The five through holes **7T8** shown in FIG. **8** are connected to the five through holes **7T9**, respectively.

Further formed in the dielectric layer **39** are five through holes **8T9** constituting respective portions of the five through hole lines **8T**. The five through holes **8T8** shown in FIG. **8** are connected to the five through holes **8T9**, respectively.

Further formed in the dielectric layer **39** are a plurality of through holes **63T9** constituting respective portions of the plurality of through hole lines **63T**. All the through holes represented by circles in FIG. **9**, except the through holes **7T9** and **8T9**, are the through holes **63T9**. The plurality of through holes **63T8** shown in FIG. **8** are connected to the plurality of through holes **63T9**, respectively.

FIG. **10** illustrates a patterned surface of each of the tenth to seventeenth dielectric layers **40** to **47**. Five through holes **7T10** constituting respective portions of the five through hole lines **7T** are formed in each of the dielectric layers **40** to **47**. The five through holes **7T9** shown in FIG. **9** are respectively connected to the five through holes **7T10** formed in the tenth dielectric layer **40**.

In each of the dielectric layers **40** to **47**, there are further formed five through holes **8T10** constituting respective portions of the five through hole lines **8T**. The five through holes **8T9** shown in FIG. **9** are respectively connected to the five through holes **8T10** formed in the tenth dielectric layer **40**.

Further, a plurality of through holes **63T10** constituting respective portions of the plurality of through hole lines **63T** are formed in each of the dielectric layers **40** to **47**. All the through holes represented by circles in FIG. **10**, except the through holes **7T10** and **8T10**, are the through holes **63T10**. The plurality of through holes **63T9** shown in FIG. **9** are respectively connected to the plurality of through holes **63T10** formed in the tenth dielectric layer **40**.

In the dielectric layers **40** to **47**, every vertically adjacent through holes denoted by the same reference signs are connected to each other.

FIG. **11** illustrates a patterned surface of the eighteenth dielectric layer **48**. The second conductor layer **481** forming the second portion **62** of the shield **6** is formed on the patterned surface of the dielectric layer **48**. The through holes **7T10**, **8T10** and **63T10** formed in the seventeenth dielectric layer **47** are connected to the second conductor layer **481**.

The band-pass filter **1** according to the present embodiment is formed by stacking the first to eighteenth dielectric layers **31** to **48** such that the patterned surface of the first dielectric layer **31** also serves as the first end face **2A** of the main body **2**. A surface of the eighteenth dielectric layer **48** opposite to the patterned surface serves as the second end face **2B** of the main body **2**. The first to eighteenth dielectric layers **31** to **48** constitute the multilayer stack **20**.

The respective resonator conductor portions **510**, **520**, **530**, **540** and **550** of the resonators **51** to **55** are located at the same position in the multilayer stack **20** in the first direction, i.e., the Z direction.

The conductor layer **311** forming the first input/output port **3** is connected to the conductor layer **381** shown in FIG. **8** via the through hole **31T1**, the conductor layer **321** and the through holes **32T1**, **33T1**, **34T1** and **35T1**. The conductor layer **381** is opposed to a portion of the resonator conductor portion **510** (FIG. **9**) near the first end **510a** with the dielectric layer **38** interposed therebetween. The capacitor **C1** shown in FIG. **2** is composed of the conductor layer **381** and the resonator conductor portion **510**, and also the dielectric layer **38** interposed therebetween.

The conductor layer **312** forming the second input/output port **4** is connected to the conductor layer **382** shown in FIG. **8** via the through hole **31T2**, the conductor layer **322** and the through holes **32T2**, **33T2**, **34T2** and **35T2**. The conductor layer **382** is opposed to a portion of the resonator conductor portion **550** (FIG. **9**) near the first end **550a** with the dielectric layer **38** interposed therebetween. The capacitor **C2** shown in FIG. **2** is composed of the conductor layer **382** and the resonator conductor portion **550**, and also the dielectric layer **38** interposed therebetween.

The conductor layer **383** shown in FIG. **8** is opposed to a portion of the resonator conductor portion **510** near the second end **510b** and to a portion of the resonator conductor portion **520** near the first end **520a**, with the dielectric layer **38** interposed between the conductor layer **383** and each of the aforementioned respective portions of the resonator conductor portions **510** and **520**. The capacitor **C12** shown in FIG. **2** is composed of the conductor layer **383**, the resonator conductor portions **510** and **520**, and the dielectric layer **38** interposed between the conductor layer **383** and the resonator conductor portions **510** and **520**.

The conductor layer **384** shown in FIG. **8** is opposed to a portion of the resonator conductor portion **520** near the second end **520b** and to a portion of the resonator conductor portion **530** near the first end **530a**, with the dielectric layer **38** interposed between the conductor layer **384** and each of the aforementioned respective portions of the resonator conductor portions **520** and **530**. The capacitor **C23** shown in FIG. **2** is composed of the conductor layer **384**, the resonator conductor portions **520** and **530**, and the dielectric layer **38** interposed between the conductor layer **384** and the resonator conductor portions **520** and **530**.

The conductor layer **385** shown in FIG. **8** is opposed to a portion of the resonator conductor portion **530** near the second end **530b** and to a portion of the resonator conductor portion **540** near the second end **540b**, with the dielectric layer **38** interposed between the conductor layer **385** and each of the aforementioned respective portions of the resonator conductor portions **530** and **540**. The capacitor **C34** shown in FIG. **2** is composed of the conductor layer **385**, the resonator conductor portions **530** and **540**, and the dielectric layer **38** interposed between the conductor layer **385** and the resonator conductor portions **530** and **540**.

The conductor layer **386** shown in FIG. **8** is opposed to a portion of the resonator conductor portion **540** near the first end **540a** and to a portion of the resonator conductor portion **550** near the second end **550b**, with the dielectric layer **38** interposed between the conductor layer **386** and each of the aforementioned respective portions of the resonator conductor portions **540** and **550**. The capacitor **C45** shown in FIG. **2** is composed of the conductor layer **386**, the resonator conductor portions **540** and **550**, and the dielectric layer **38**

interposed between the conductor layer **386** and the resonator conductor portions **540** and **550**.

Each of the five through hole lines **7T** of the first partition **7** is formed by connecting the through holes **7T1**, **7T2**, **7T3**, **7T4**, **7T5**, **7T8**, **7T9** and **7T10** in series in the Z direction.

In the example shown in FIG. **3** to FIG. **11**, part of the first partition **7** extends to pass between the second portion **510B** of the resonator conductor portion **510** and the second portion **550B** of the resonator conductor portion **550**, and is in contact with the first portion **61** and the second portion **62**.

Each of the five through hole lines **8T** of the second partition **8** is formed by connecting the through holes **8T1**, **8T2**, **8T3**, **8T4**, **8T5**, **8T8**, **8T9** and **8T10** in series in the Z direction.

Each of the plurality of through hole lines **63T** of the connecting portion **63** is formed by connecting the through holes **63T1**, **63T2**, **63T3**, **63T4**, **63T5**, **63T8**, **63T9** and **63T10** in series in the Z direction.

In the present embodiment, the resonators **51** and **55** which are not adjacent to each other in circuit configuration are magnetically coupled to each other, while the resonators **52** and **54** which are not adjacent to each other in circuit configuration are capacitively coupled to each other. The resonator **51** and the resonator **52** are adjacent to each other in circuit configuration and are also capacitively coupled to each other. The resonator **55** and the resonator **54** are adjacent to each other in circuit configuration and are also capacitively coupled to each other. The resonator conductor portions **510**, **520**, **540**, and **550** of the resonators **51**, **52**, **54**, and **55** having such relationships in circuit configuration have the following physical relationships with each other.

The resonator conductor portion **510** of the resonator **51** and the resonator conductor portion **550** of the resonator **55** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. In the present embodiment, in particular, the second portion **510B** of the resonator conductor portion **510** and the second portion **550B** of the resonator conductor portion **550**, both of which extend in the Y direction, are physically adjacent to each other in the X direction without any resonator conductor portion of another resonator therebetween. The magnetic coupling between the resonators **51** and **55** is thereby achieved.

The resonator conductor portion **520** of the resonator **52** and the resonator conductor portion **540** of the resonator **54** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. In the present embodiment, in particular, the first end **520a** of the resonator conductor portion **520** and the first end **540a** of the resonator conductor portion **540** are at a small distance from each other and adjacent to each other, without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **52** and **54** is thereby achieved.

The resonator conductor portion **510** of the resonator **51** and the resonator conductor portion **520** of the resonator **52** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **51** and **52** is thereby achieved easily.

The resonator conductor portion **540** of the resonator **54** and the resonator conductor portion **550** of the resonator **55** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **54** and **55** is thereby achieved easily.

The function and effects of the band-pass filter **1** according to the present embodiment will now be described. For example, the band-pass filter **1** is designed and configured to have a passband in a quasi-millimeter wave band of 10 to 30 GHz or a millimeter wave band of 30 to 300 GHz.

The band-pass filter **1** includes the resonators **51**, **52**, **53**, **54** and **55** which are provided between the first input/output port **3** and the second input/output port **4** and arranged in the listed order, from closest to farthest from the first input/output port **3**. The resonators **51** to **55** are configured so that electromagnetic coupling, more specifically, capacitive coupling, is established between every two of the resonators adjacent to each other in circuit configuration.

The band-pass filter **1** includes the shield **6**. The shield **6** has the function of preventing electromagnetic radiation to the surroundings of the band-pass filter **1**. In the present embodiment, the shield **6** and the dielectric inside the shield **6** constitute a structure similar to a waveguide, thereby generating one or more waveguide modes. The one or more waveguide modes usually have resonance frequencies in a frequency region higher than the passband of the band-pass filter **1**. If one of the waveguide modes that is the lowest in resonance frequency, i.e., the lowest-order waveguide mode, has a resonance frequency relatively close to the passband of the band-pass filter **1**, there occurs the problem that the attenuation characteristic in the frequency region above the passband deteriorates due to unwanted resonance at the resonance frequency of the lowest-order waveguide mode.

The band-pass filter **1** according to the present embodiment prevents the occurrence of the foregoing problem by the provision of the first and second partitions **7** and **8**. This will be described in detail below. Assuming that there are no partitions **7** and **8**, the resonance frequency of the lowest-order waveguide mode depends on the shape of the space defined by the shield **6**. Typically, the larger the space, the lower the resonance frequency of the lowest-order waveguide mode.

In the present embodiment, the first and second partitions **7** and **8** divide the space defined by the shield **6** into a plurality of spaces. Specifically, in the present embodiment, the first partition **7** divides the space defined by the shield **6** into a space in which the resonator conductor portion **510** is located and a space in which the resonator conductor portion **550** is located.

In the present embodiment, the resonance frequency of the lowest-order waveguide mode depends on the shape of each of the plurality of spaces divided by the first and second partitions **7** and **8**. Each of these plurality of spaces is smaller than the space defined by the shield **6** in the absence of the partitions **7** and **8**. The present invention thus makes the resonance frequency of the lowest-order waveguide mode higher than in the case where there are no partitions **7** and **8**. Consequently, the band-pass filter **1** according to the present embodiment prevents the attenuation characteristic in the frequency region above the passband from being degraded by the lowest-order waveguide mode.

In the present embodiment, the first stage resonator **51** and the fifth stage resonator **55**, which are not adjacent to each other in circuit configuration, are magnetically coupled to each other. This enables creation of an attenuation pole in at least one of two frequency regions in a frequency response of insertion loss. One of the two frequency regions is a first passband-vicinity region, which is a frequency region close to the passband and lower than the passband, and the other is a second passband-vicinity region, which is a frequency region close to the passband and higher than the passband. Note that the passband is, for example, a frequency band

between two frequencies at which the insertion loss becomes higher by 3 dB than its minimum value.

In the present embodiment, specifically, the magnetic coupling between the first stage resonator **51** and the fifth stage resonator **55** creates an attenuation pole in the first passband-vicinity region.

In the present embodiment, the second stage resonator **52** and the fourth stage resonator **54**, which are not adjacent to each other in circuit configuration, are capacitively coupled to each other. This enables creation of an attenuation pole in the second passband-vicinity region.

By virtue of these features, the present embodiment provides the band-pass filter **1** which includes the five resonators **51** and **55** and the shield **6** and has favorable characteristics. In the present embodiment, the favorable characteristics of the band-pass filter **1** specifically refer to steep changes in the insertion loss in both of the first and second passband-vicinity regions, and prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode.

In the present embodiment, at least part of the first partition **7** extends to pass between the resonator conductor portion **510** and the resonator conductor portion **550**. The resonator conductor portion **510** and the resonator conductor portion **550** respectively constitute the resonator **51** and the resonator **55**, which are magnetically coupled to each other although not adjacent to each other in circuit configuration. The magnetic coupling between the resonators **51** and **55** can be weaker than the electromagnetic coupling between any two resonators that are adjacent to each other in circuit configuration. According to the present embodiment, it is thus possible to establish magnetic coupling between the resonators **51** and **55** while disposing the first partition **7** such that at least part thereof passes between the resonator conductor portion **510** and the resonator conductor portion **550**. The present embodiment thus achieves both of prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode by the provision of the first partition **7** and the creation of an attenuation pole by establishing magnetic coupling between the resonators **51** and **55**. This results in the favorable characteristics of the band-pass filter **1**.

Each of the five resonators **51** to **55** in the present embodiment is a half-wave resonator. In this case, each of the resonator conductor portions **510**, **520**, **530**, **540** and **550** may have a harmonic resonance mode in addition to a basic resonance mode, the basic resonance mode having a basic resonance frequency which determines the passband, the harmonic resonance mode having a resonance frequency twice as high as the basic resonance frequency. The harmonic resonance mode may degrade the attenuation characteristic in a frequency region above the passband.

To address this problem, the band-pass filter **1** according to the present embodiment has the notch filter section capable of attenuating signals having a resonance frequency twice as high as the basic resonance frequency. The present embodiment thereby prevents the attenuation characteristic from being degraded by the harmonic resonance mode.

In the present embodiment, the resonator conductor portions **510**, **520**, **540** and **550** of the resonators **51**, **52**, **54** and **55** having the above-described relationship in circuit configuration are configured to have the above-described physical relationship. The present embodiment thus realizes the band-pass filter **1** which has two cross couplings and is simple in structure.

Now, an example of characteristics of the band-pass filter **1** according to the present embodiment and an example of

characteristics of a band-pass filter of a first comparative example will be discussed. The band-pass filter of the first comparative example has the same configuration as that of the band-pass filter **1** except that the first partition **7** is omitted.

FIG. **12** illustrates an example frequency response of the insertion loss of the band-pass filter **1** according to the present embodiment. FIG. **13** illustrates an example frequency response of the insertion loss of the band-pass filter of the first comparative example. The frequency responses shown in FIGS. **12** and **13** were obtained by simulation. In FIGS. **12** and **13**, the horizontal axis represents frequency, and the vertical axis represents insertion loss. In the examples shown in FIGS. **12** and **13**, the band-pass filter **1** and the band-pass filter of the first comparative example have a passband of approximately 26 to 30 GHz, and the center frequency of the passband is approximately 28 GHz.

For the band-pass filter **1** used in the simulation, the magnitudes of the two cross couplings were adjusted, based on the presence of the first partition **7**, so as to create attenuation poles in both of the first passband-vicinity region and the second passband-vicinity region, as shown in FIG. **12**. The first passband-vicinity region is a frequency region of approximately 24 to 26 GHz. The second passband-vicinity region is a frequency region of approximately 30 to 32 GHz. As illustrated in FIG. **13**, the characteristic of the band-pass filter of the first comparative example shows no attenuation pole in the first passband-vicinity region, and shows a lower insertion loss than that of the band-pass filter **1** at an attenuation pole in the second passband-vicinity region. This is because, for the band-pass filter of the first comparative example, the omission of the first partition **7** resulted in a deviation of the magnitude of the magnetic coupling between the resonators **51** and **55** from the adjusted magnitude in the band-pass filter **1**.

Further, the characteristic of the band-pass filter of the first comparative example shown in FIG. **13** exhibits a peak of an extreme reduction in the insertion loss at approximately 40 GHz. This is considered to be due to unwanted resonance caused by the lowest-order waveguide mode at approximately 40 GHz. In contrast, the characteristic of the band-pass filter **1** shown in FIG. **12** exhibits no such peak as that occurring in the characteristic shown in FIG. **13**, and thus exhibits a better attenuation characteristic in a frequency region above the passband, when compared with the characteristic shown in FIG. **13**.

Further, the characteristic of the band-pass filter **1** shown in FIG. **12** exhibits an increase in the insertion loss at approximately 55 GHz. This is due to the effect of the notch filter section.

It is apparent from FIG. **12** that the band-pass filter **1** according to the present embodiment provides the favorable characteristics achieving steep changes in the insertion loss in both of the first and second passband-vicinity regions and prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode.

#### Second Embodiment

A second embodiment of the present invention will now be described. First, the configuration of a band-pass filter according to the present embodiment will be described with reference to FIG. **14** and FIG. **15**. FIG. **14** is a perspective view illustrating the structure of the band-pass filter according to the second embodiment. FIG. **15** is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the second embodiment.

The band-pass filter 100 according to the present embodiment includes the main body 2, the first input/output port 3, the second input/output port 4, three or more resonators, the shield 6, a partition 107, and a coupling adjustment section 108. The main body 2 includes the multilayer stack 20.

The three or more resonators are located between the first input/output port 3 and the second input/output port 4 in circuit configuration. In the present embodiment, the three or more resonators are six resonators 151, 152, 153, 154, 155 and 156. The six resonators 151, 152, 153, 154, 155 and 156 are arranged in this order, from closest to farthest, from the first input/output port 3 in circuit configuration. The six resonators 151 to 156 are configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration. Specifically, the resonators 151 to 156 are configured so that the resonators 151 and 152 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators 152 and 153 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators 153 and 154 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators 154 and 155 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, and the resonators 155 and 156 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other. In the present embodiment, the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is specifically capacitive coupling. In the present embodiment, each of the resonators 151 to 156 is a resonator with open ends, and also a half-wave resonator.

The first portion 61, the second portion 62 and the connecting portion 63 of the shield 6 are arranged to surround the six resonators 151 to 156. The first portion 61 is formed of a first conductor layer 1313 disposed on the first end face 21a of the main portion 21 of the multilayer stack 20. The second portion 62 is formed of a second conductor layer 1521 disposed on the second end face 21b of the main portion 21 of the multilayer stack 20.

The band-pass filter 100 includes a capacitor C112 for establishing capacitive coupling between the resonators 151 and 152, a capacitor C123 for establishing capacitive coupling between the resonators 152 and 153, a capacitor C134 for establishing capacitive coupling between the resonators 153 and 154, a capacitor C145 for establishing capacitive coupling between the resonators 154 and 155, and a capacitor C156 for establishing capacitive coupling between the resonators 155 and 156.

In the present embodiment, among the six resonators 151 to 156, the resonator 152, which is the second closest to the first input/output port 3 in circuit configuration, and the resonator 155, which is the second closest to the second input/output port 4 in circuit configuration, are magnetically coupled to each other although they are not adjacent to each other in circuit configuration. The resonator 152 corresponds to the first resonator in the present invention. The resonator 155 corresponds to the second resonator in the present invention.

Further, in the present embodiment, among the six resonators 151 to 156, the resonator 151, which is the closest to the first input/output port 3 in circuit configuration, and the resonator 156, which is the closest to the second input/output port 4 in circuit configuration, are capacitively coupled to each other although they are not adjacent to each other in

circuit configuration. In FIG. 15, the capacitor symbol C116 represents the capacitive coupling between the resonators 151 and 156.

The band-pass filter 100 further includes a capacitor C101 provided between the first input/output port 3 and the resonator 151, and a capacitor C102 provided between the second input/output port 4 and the resonator 156.

The band-pass filter 100 further includes the two lines 91 and 92 as in the first embodiment.

The resonator 151 includes a resonator conductor portion 1510 formed of a conductor. The resonator 152 includes a resonator conductor portion 1520 formed of a conductor. The resonator 153 includes a resonator conductor portion 1530 formed of a conductor. The resonator 154 includes a resonator conductor portion 1540 formed of a conductor. The resonator 155 includes a resonator conductor portion 1550 formed of a conductor. The resonator 156 includes a resonator conductor portion 1560 formed of a conductor. The resonator conductor portion 1520 corresponds to the first resonator conductor portion in the present invention. The resonator conductor portion 1550 corresponds to the second resonator conductor portion in the present invention.

Each of the resonator conductor portions 1510, 1520, 1530, 1540, 1550 and 1560 extends in a direction intersecting the first direction or the Z direction. In the present embodiment, specifically, each of the resonator conductor portions 1510, 1520, 1530, 1540, 1550 and 1560 extends in a direction orthogonal to the first direction or the Z direction.

Each of the resonator conductor portions 1510, 1520, 1530, 1540, 1550 and 1560 has a first end and a second end opposite to each other. As mentioned above, each of the resonators 151 to 156 is a resonator with open ends. Thus, both of the first and second ends of each of the resonator conductor portions 1510, 1520, 1530, 1540, 1550 and 1560 are open. Each of the resonator conductor portions 1510, 1520, 1530, 1540, 1550 and 1560 has a length of one half or nearly one half the wavelength corresponding to the center frequency of the passband of the band-pass filter 100.

The partition 107 is in contact with the first portion 61 and the second portion 62. At least part of the partition 107 extends to pass between the resonator conductor portion 1520 and the resonator conductor portion 1550. In the present embodiment, specifically, the partition 107 extends in the first direction, i.e., the Z direction. The partition 107 connects the first portion 61 and the second portion 62 via the shortest path. To be more specific, the length of the partition 107 in the Z direction is equal to the distance between the first portion 61 and the second portion 62.

The partition 107 runs through the two or more dielectric layers constituting the main portion 21. In the present embodiment, the partition 107 includes a plurality of through hole lines 107T each running through the two or more dielectric layers constituting the main portion 21, and includes a conductor layer 107C. The plurality of through hole lines 107T correspond to the plurality of first through hole lines in the present invention. In FIG. 14, each through hole line 107T is represented by a circular column. Each of the through hole lines 107T includes two or more through holes connected in series. Each of the through hole lines 107T extends in the Z direction. The through hole lines 107T are arranged to be adjacent to each other in the Y direction. In the present embodiment, the number of the through hole lines 107T is seven.

The coupling adjustment section 108 is intended to adjust the magnitude of the capacitive coupling between the resonators 151 and 156. The coupling adjustment section 108 includes a plurality of through hole lines 108T each running

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through the two or more dielectric layers constituting the main portion 21. In FIG. 14, each through hole line 108T is represented by a circular column. Each of the through hole lines 108T includes two or more through holes connected in series. Each of the through hole lines 108T extends in the Z direction and is in contact with the first portion 61 and the second portion 62. The through hole lines 108T are arranged to be adjacent to each other in the Y direction in the vicinity of the second end of the resonator conductor portion 1510 and the second end of the resonator conductor portion 1560. In the present embodiment, the number of the through hole lines 108T is two.

The connecting portion 63 of the shield 6 includes a plurality of through hole lines 163T each running through the two or more dielectric layers constituting the main portion 21. The plurality of through hole lines 163T correspond to the second through hole lines in the present invention. In FIG. 14, each through hole line 163T is represented by a circular column. All the through hole lines represented by circular columns in FIG. 14, except the seven through hole lines 107T and the two through hole lines 108T, are the through hole lines 163T. Each of the through hole lines 163T includes two or more through holes connected in series. Each of the through hole lines 163T extends in the Z direction.

Reference is now made to FIG. 16 to FIG. 24 to describe an example of a plurality of dielectric layers constituting the multilayer stack 20 and the configuration of a plurality of conductor layers formed on the dielectric layers and a plurality of through holes formed in the dielectric layers. In this example, the multilayer stack 20 includes twenty-two dielectric layers stacked together. The twenty-two dielectric layers will be referred to as the first to twenty-second dielectric layers in the order from bottom to top. The first to twenty-second dielectric layers are denoted by reference numerals 131 to 152, respectively. The main portion 21 is composed of the first to twenty-first dielectric layers 131 to 151. The coating portion 22 is composed of the twenty-second dielectric layer 152. In FIG. 16 to FIG. 23, each circle represents a through hole.

FIG. 16 illustrates a patterned surface of the first dielectric layer 131. On the patterned surface of the first dielectric layer 131, there are formed a conductor layer 1311 forming the first input/output port 3, a conductor layer 1312 forming the second input/output port 4, and the first conductor layer 1313 forming the first portion 61 of the shield 6.

Further, a through hole 131T1 connected to the conductor layer 1311, and a through hole 131T2 connected to the conductor layer 1312 are formed in the dielectric layer 131. Further formed in the dielectric layer 131 are seven through holes 107T1 constituting respective portions of the seven through hole lines 107T, two through holes 108T1 constituting respective portions of the two through hole lines 108T, and a plurality of through holes 163T1 constituting respective portions of the plurality of through hole lines 163T. All the through holes represented by circles in FIG. 16, except the through holes 131T1, 131T2, 107T1 and 108T1, are the through holes 163T1. The through holes 107T1, 108T1 and 163T1 are connected to the first conductor layer 1313.

FIG. 17 illustrates a patterned surface of each of the second and third dielectric layers 132 and 133. Through holes 132T1 and 132T2 are formed in each of the dielectric layers 132 and 133. The through holes 131T1 and 131T2 shown in FIG. 16 are connected to the through holes 132T1 and 132T2, respectively.

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In each of the dielectric layers 132 and 133, there are further formed seven through holes 107T2 constituting respective portions of the seven through hole lines 107T. The seven through holes 107T1 shown in FIG. 16 are respectively connected to the seven through holes 107T2 formed in the second dielectric layer 132.

In each of the dielectric layers 132 and 133, there are further formed two through holes 108T2 constituting respective portions of the two through hole lines 108T. The two through holes 108T1 shown in FIG. 16 are respectively connected to the two through holes 108T2 formed in the second dielectric layer 132.

Further, a plurality of through holes 163T2 constituting respective portions of the plurality of through hole lines 163T are formed in each of the dielectric layers 132 and 133. All the through holes represented by circles in FIG. 17, except the through holes 132T1, 132T2, 107T2 and 108T2, are the through holes 163T2. The plurality of through holes 163T1 shown in FIG. 16 are respectively connected to the plurality of through holes 163T2 formed in the second dielectric layer 132.

In the dielectric layers 132 and 133, every vertically adjacent through holes denoted by the same reference signs are connected to each other.

FIG. 18 illustrates a patterned surface of the fourth dielectric layer 134. On the patterned surface of the dielectric layer 134, there are formed a conductor layer 1341 forming the line 91 and a conductor layer 1342 forming the line 92. Each of the conductor layers 1341 and 1342 has a first end and a second end opposite to each other. The through hole 132T1 formed in the third dielectric layer 133 is connected to a portion of the conductor layer 1341 near the first end thereof. The through hole 132T2 formed in the third dielectric layer 133 is connected to a portion of the conductor layer 1342 near the first end thereof. A portion of the conductor layer 1341 near the second end thereof and a portion of the conductor layer 1342 near the second end thereof are opposed to the conductor layer 1313 shown in FIG. 16 with the dielectric layers 131, 132 and 133 interposed between the conductor layer 1313 and each of the aforementioned portions of the conductor layers 1341 and 1342.

Further formed in the dielectric layer 134 are a through hole 134T1 connected to the portion of the conductor layer 1341 near the first end thereof, and a through hole 134T2 connected to the portion of the conductor layer 1342 near the first end thereof.

Further, seven through holes 107T4 constituting respective portions of the seven through hole lines 107T are formed in the dielectric layer 134. The seven through holes 107T2 formed in the third dielectric layer 133 are connected to the seven through holes 107T4, respectively.

Further formed in the dielectric layer 134 are two through holes 108T4 constituting respective portions of the two through hole lines 108T. The two through holes 108T2 formed in the third dielectric layer 133 are connected to the two through holes 108T4, respectively.

Further formed in the dielectric layer 134 are a plurality of through holes 163T4 constituting respective portions of the plurality of through hole lines 163T. All the through holes represented by circles in FIG. 18, except the through holes 134T1, 134T2, 107T4 and 108T4, are the through holes 163T4. The plurality of through holes 163T2 formed in the third dielectric layer 133 are connected to the plurality of through holes 163T4, respectively.

FIG. 19 illustrates a patterned surface of each of the fifth to ninth dielectric layers 135 to 139. Through holes 135T1

and **135T2** are formed in each of the dielectric layers **135** to **139**. The through holes **134T1** and **134T2** shown in FIG. **18** are respectively connected to the through holes **135T1** and **135T2** formed in the fifth dielectric layer **135**.

In each of the dielectric layers **135** to **139**, there are further formed seven through holes **107T5** constituting respective portions of the seven through hole lines **107T**. The seven through holes **107T4** shown in FIG. **18** are respectively connected to the seven through holes **107T5** formed in the fifth dielectric layer **135**.

In each of the dielectric layers **135** to **139**, there are further formed two through holes **108T5** constituting respective portions of the two through hole lines **108T**. The two through holes **108T4** shown in FIG. **18** are respectively connected to the two through holes **108T5** formed in the fifth dielectric layer **135**.

Further, a plurality of through holes **163T5** constituting respective portions of the plurality of through hole lines **163T** are formed in each of the dielectric layers **135** to **139**. All the through holes represented by circles in FIG. **19**, except the through holes **135T1**, **135T2**, **107T5** and **108T5**, are the through holes **163T5**. The plurality of through holes **163T4** shown in FIG. **18** are respectively connected to the plurality of through holes **163T5** formed in the fifth dielectric layer **135**.

In the dielectric layers **135** to **139**, every vertically adjacent through holes denoted by the same reference signs are connected to each other.

FIG. **20** illustrates a patterned surface of the tenth dielectric layer **140**. On the patterned surface of the dielectric layer **140**, there are formed a conductor layer **1401** for forming the capacitor **C101** shown in FIG. **15** and a conductor layer **1402** for forming the capacitor **C102** shown in FIG. **15**. The through hole **135T1** formed in the ninth dielectric layer **139** is connected to the conductor layer **1401**. The through hole **135T2** formed in the ninth dielectric layer **139** is connected to the conductor layer **1402**.

On the patterned surface of the dielectric layer **140**, there are further formed conductor layers **1403**, **1404**, **1405**, **1406** and **1407** for forming the capacitors **C112**, **C123**, **C134**, **C145** and **C156** shown in FIG. **15**, respectively.

Further, seven through holes **107T10** constituting respective portions of the seven through hole lines **107T** are formed in the dielectric layer **140**. The seven through holes **107T5** formed in the ninth dielectric layer **139** are connected to the seven through holes **107T10**, respectively.

Further formed in the dielectric layer **140** are two through holes **108T10** constituting respective portions of the two through hole lines **108T**. The two through holes **108T5** formed in the ninth dielectric layer **139** are connected to the two through holes **108T10**, respectively.

Further formed in the dielectric layer **140** are a plurality of through holes **163T10** constituting respective portions of the plurality of through hole lines **163T**. All the through holes represented by circles in FIG. **20**, except the through holes **107T10** and **108T10**, are the through holes **163T10**. The plurality of through holes **163T5** formed in the ninth dielectric layer **139** are connected to the plurality of through holes **163T10**, respectively.

FIG. **21** illustrates a patterned surface of the eleventh dielectric layer **141**. In the dielectric layer **141**, there are formed seven through holes **107T11** constituting respective portions of the seven through hole lines **107T**. The seven through holes **107T10** shown in FIG. **20** are connected to the seven through holes **107T11**, respectively.

Further formed in the dielectric layer **141** are two through holes **108T11** constituting respective portions of the two

through hole lines **108T**. The two through holes **108T10** shown in FIG. **20** are connected to the two through holes **108T11**, respectively.

Further formed in the dielectric layer **141** are a plurality of through holes **163T11** constituting respective portions of the plurality of through hole lines **163T**. All the through holes represented by circles in FIG. **21**, except the through holes **107T11** and **108T11**, are the through holes **163T11**. The plurality of through holes **163T10** shown in FIG. **20** are connected to the plurality of through holes **163T11**, respectively.

FIG. **22** illustrates a patterned surface of the twelfth dielectric layer **142**. The resonator conductor portions **1510**, **1520**, **1530**, **1540**, **1550** and **1560** are formed on the patterned surface of the dielectric layer **142**.

The resonator conductor portion **1510** has a first end **1510a** and a second end **1510b** opposite to each other. The resonator conductor portion **1520** has a first end **1520a** and a second end **1520b** opposite to each other. The resonator conductor portion **1530** has a first end **1530a** and a second end **1530b** opposite to each other. The resonator conductor portion **1540** has a first end **1540a** and a second end **1540b** opposite to each other. The resonator conductor portion **1550** has a first end **1550a** and a second end **1550b** opposite to each other. The resonator conductor portion **1560** has a first end **1560a** and a second end **1560b** opposite to each other.

Each of the resonator conductor portions **1510** and **1560** extends in the X direction. The resonator conductor portions **1510** and **1560** are arranged in such a positional relationship that one straight line extends across the resonator conductor portions **1510** and **1560** in the X direction. The second end **1510b** of the resonator conductor portion **1510** and the second end **1560b** of the resonator conductor portion **1560** are at a predetermined distance from each other and adjacent to each other. The distance between the second end **1510b** and the second end **1560b** is sufficiently smaller than the length of each of the resonator conductor portions **1510** and **1560**.

Each of the resonator conductor portions **1520** and **1550** extends in the Y direction. The resonator conductor portions **1520** and **1550** are at a predetermined distance from each other and adjacent to each other in the X direction. The distance between the resonator conductor portions **1520** and **1550** is smaller than the length of each of the resonator conductor portions **1520** and **1550**.

The first end **1520a** of the resonator conductor portion **1520** is located near the second end **1510b** of the resonator conductor portion **1510**. The first end **1550a** of the resonator conductor portion **1550** is located near the second end **1560b** of the resonator conductor portion **1560**.

The resonator conductor portion **1530** includes a first portion **1530A**, a second portion **1530B** and a third portion **1530C**. The first portion **1530A** includes the first end **1530a**, and the second portion **1530B** includes the second end **1530b**. The first portion **1530A** extends in the X direction, and the second portion **1530B** extends in the Y direction. The third portion **1530C** connects an end of the first portion **1530A** opposite from the first end **1530a** and an end of the second portion **1530B** opposite from the second end **1530b**. In FIG. **22**, the boundary between the first portion **1530A** and the third portion **1530C** and the boundary between the second portion **1530B** and the third portion **1530C** are shown by broken lines. The first end **1530a** is located near the second end **1520b** of the resonator conductor portion **1520**.

The resonator conductor portion **1540** includes a first portion **1540A**, a second portion **1540B** and a third portion

**1540C**. The first portion **1540A** includes the first end **1540a**, and the second portion **1540B** includes the second end **1540b**. The first portion **1540A** extends in the X direction, and the second portion **1540B** extends in the Y direction. The third portion **1540C** connects an end of the first portion **1540A** opposite from the first end **1540a** and an end of the second portion **1540B** opposite from the second end **1540b**. In FIG. 22, the boundary between the first portion **1540A** and the third portion **1540C** and the boundary between the second portion **1540B** and the third portion **1540C** are shown by broken lines. The first end **1540a** is located near the second end **1550b** of the resonator conductor portion **1550**.

The first end **1530a** of the resonator conductor portion **1530** and the first end **1540a** of the resonator conductor portion **1540** are at a predetermined distance from each other and adjacent to each other.

The conductor layer **107C** constituting part of the partition **107** is further formed on the patterned surface of the dielectric layer **142**. The conductor layer **107C** is situated between the resonator conductor portion **1520** and the resonator conductor portion **1550**, and extends in the Y direction.

Further, seven through holes **107T12** constituting respective portions of the seven through hole lines **107T** are formed in the dielectric layer **142**. The seven through holes **107T12** are connected to the conductor layer **107C**. The seven through holes **107T11** shown in FIG. 21 are connected to the seven through holes **107T12**, respectively.

Further formed in the dielectric layer **142** are two through holes **108T12** constituting respective portions of the two through hole lines **108T**. The two through holes **108T11** shown in FIG. 21 are connected to the two through holes **108T12**, respectively.

Further formed in the dielectric layer **142** are a plurality of through holes **163T12** constituting respective portions of the plurality of through hole lines **163T**. All the through holes represented by circles in FIG. 22, except the through holes **107T12** and **108T12**, are the through holes **163T12**. The plurality of through holes **163T11** shown in FIG. 21 are connected to the plurality of through holes **163T12**, respectively.

FIG. 23 illustrates a patterned surface of each of the thirteenth to twenty-first dielectric layers **143** to **151**. Seven through holes **107T13** constituting respective portions of the seven through hole lines **107T** are formed in each of the dielectric layers **143** to **151**. The seven through holes **107T12** shown in FIG. 22 are respectively connected to the seven through holes **107T13** formed in the thirteenth dielectric layer **143**.

In each of the dielectric layers **143** to **151**, there are further formed two through holes **108T13** constituting respective portions of the two through hole lines **108T**. The two through holes **108T12** shown in FIG. 22 are respectively connected to the two through holes **108T13** formed in the thirteenth dielectric layer **143**.

Further, a plurality of through holes **163T13** constituting respective portions of the plurality of through hole lines **163T** are formed in each of the dielectric layers **143** to **151**. All the through holes represented by circles in FIG. 23, except the through holes **107T13** and **108T13**, are the through holes **163T13**. The plurality of through holes **163T12** shown in FIG. 22 are respectively connected to the plurality of through holes **163T13** formed in the thirteenth dielectric layer **143**.

In the dielectric layers **143** to **151**, every vertically adjacent through holes denoted by the same reference signs are connected to each other.

FIG. 24 illustrates a patterned surface of the twenty-second dielectric layer **152**. The second conductor layer **1521** forming the second portion **62** of the shield **6** is formed on the patterned surface of the dielectric layer **152**. The through holes **107T13**, **108T13** and **163T13** formed in the twenty-first dielectric layer **151** are connected to the second conductor layer **1521**.

The band-pass filter **100** according to the present embodiment is formed by stacking the first to twenty-second dielectric layers **131** to **152** such that the patterned surface of the first dielectric layer **131** also serves as the first end face **2A** of the main body **2**. A surface of the twenty-second dielectric layer **152** opposite to the patterned surface serves as the second end face **2B** of the main body **2**. The first to twenty-second dielectric layers **131** to **152** constitute the multilayer stack **20**.

The respective resonator conductor portions **1510**, **1520**, **1530**, **1540**, **1550** and **1560** of the resonators **151** to **156** are located at the same position in the multilayer stack **20** in the first direction, i.e., the Z direction.

The conductor layer **1311** forming the first input/output port **3** is connected to the conductor layer **1401** shown in FIG. 20 via the through holes **131T1**, **132T1**, **134T1** and **135T1**. The conductor layer **1401** is opposed to a portion of the resonator conductor portion **1510** (FIG. 22) near the first end **1510a** with the dielectric layers **140** and **141** interposed therebetween. The capacitor **C101** shown in FIG. 15 is composed of the conductor layer **1401** and the resonator conductor portion **1510**, and also the dielectric layers **140** and **141** interposed therebetween.

The conductor layer **1312** forming the second input/output port **4** is connected to the conductor layer **1402** shown in FIG. 20 via the through holes **131T2**, **132T2**, **134T2** and **135T2**. The conductor layer **1402** is opposed to a portion of the resonator conductor portion **1560** (FIG. 22) near the first end **1560a** with the dielectric layers **140** and **141** interposed therebetween. The capacitor **C102** shown in FIG. 15 is composed of the conductor layer **1402** and the resonator conductor portion **1560**, and also the dielectric layers **140** and **141** interposed therebetween.

The conductor layer **1403** shown in FIG. 20 is opposed to a portion of the resonator conductor portion **1510** near the second end **1510b** and to a portion of the resonator conductor portion **1520** near the first end **1520a**, with the dielectric layers **140** and **141** interposed between the conductor layer **1403** and each of the aforementioned respective portions of the resonator conductor portions **1510** and **1520**. The capacitor **C112** shown in FIG. 15 is composed of the conductor layer **1403**, the resonator conductor portions **1510** and **1520**, and the dielectric layers **140** and **141** interposed between the conductor layer **1403** and the resonator conductor portions **1510** and **1520**.

The conductor layer **1404** shown in FIG. 20 is opposed to a portion of the resonator conductor portion **1520** near the second end **1520b** and to a portion of the resonator conductor portion **1530** near the first end **1530a**, with the dielectric layers **140** and **141** interposed between the conductor layer **1404** and each of the aforementioned respective portions of the resonator conductor portions **1520** and **1530**. The capacitor **C123** shown in FIG. 15 is composed of the conductor layer **1404**, the resonator conductor portions **1520** and **1530**, and the dielectric layers **140** and **141** interposed between the conductor layer **1404** and the resonator conductor portions **1520** and **1530**.



The conductor layer **1405** shown in FIG. **20** is opposed to a portion of the resonator conductor portion **1530** near the first end **1530a** and to a portion of the resonator conductor portion **1540** near the first end **1540a**, with the dielectric layers **140** and **141** interposed between the conductor layer **1405** and each of the aforementioned respective portions of the resonator conductor portions **1530** and **1540**. The capacitor **C134** shown in FIG. **15** is composed of the conductor layer **1405**, the resonator conductor portions **1530** and **1540**, and the dielectric layers **140** and **141** interposed between the conductor layer **1405** and the resonator conductor portions **1530** and **1540**.

The conductor layer **1406** shown in FIG. **20** is opposed to a portion of the resonator conductor portion **1540** near the first end **1540a** and to a portion of the resonator conductor portion **1550** near the second end **1550b**, with the dielectric layers **140** and **141** interposed between the conductor layer **1406** and each of the aforementioned respective portions of the resonator conductor portions **1540** and **1550**. The capacitor **C145** shown in FIG. **15** is composed of the conductor layer **1406**, the resonator conductor portions **1540** and **1550**, and the dielectric layers **140** and **141** interposed between the conductor layer **1406** and the resonator conductor portions **1540** and **1550**.

The conductor layer **1407** shown in FIG. **20** is opposed to a portion of the resonator conductor portion **1550** near the first end **1550a** and to a portion of the resonator conductor portion **1560** near the second end **1560b**, with the dielectric layers **140** and **141** interposed between the conductor layer **1407** and each of the aforementioned respective portions of the resonator conductor portions **1550** and **1560**. The capacitor **C156** shown in FIG. **15** is composed of the conductor layer **1407**, the resonator conductor portions **1550** and **1560**, and the dielectric layers **140** and **141** interposed between the conductor layer **1407** and the resonator conductor portions **1550** and **1560**.

Each of the seven through hole lines **107T** of the partition **107** is formed by connecting the through holes **107T1**, **107T2**, **107T4**, **107T5**, **107T10**, **107T11**, **107T12** and **107T13** in series in the Z direction.

In the example shown in FIG. **16** to FIG. **24**, the partition **107** extends to pass between the resonator conductor portion **1520** and the resonator conductor portion **1550**, and is in contact with the first portion **61** and the second portion **62**.

Each of the two through hole lines **108T** of the coupling adjustment section **108** is formed by connecting the through holes **108T1**, **108T2**, **108T4**, **108T5**, **108T10**, **108T11**, **108T12** and **108T13** in series in the Z direction.

Each of the plurality of through hole lines **163T** of the connecting portion **163** is formed by connecting the through holes **163T1**, **163T2**, **163T4**, **163T5**, **163T10**, **163T11**, **163T12** and **163T13** in series in the Z direction.

In the present embodiment, the resonators **152** and **155** which are not adjacent to each other in circuit configuration are magnetically coupled to each other, while the resonators **151** and **156** which are not adjacent to each other in circuit configuration are capacitively coupled to each other. The resonator **152** and the resonator **151** are adjacent to each other in circuit configuration and are also capacitively coupled to each other. The resonator **155** and the resonator **156** are adjacent to each other in circuit configuration and are also capacitively coupled to each other. The resonator conductor portions **1510**, **1520**, **1550** and **1560** of the resonators **151**, **152**, **155** and **156** having such relationships in circuit configuration have the following physical relationships with each other.

The resonator conductor portion **1520** of the resonator **152** and the resonator conductor portion **1550** of the resonator **155** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. In the present embodiment, in particular, the resonator conductor portion **1520** and the resonator conductor portion **1550**, both of which extend in the Y direction, are physically adjacent to each other in the X direction without any resonator conductor portion of another resonator therebetween. The magnetic coupling between the resonators **152** and **155** is thereby achieved.

The resonator conductor portion **1510** of the resonator **151** and the resonator conductor portion **1560** of the resonator **156** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. In the present embodiment, in particular, the second end **1510b** of the resonator conductor portion **1510** and the second end **1560b** of the resonator conductor portion **1560** are at a small distance from each other and adjacent to each other, without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **151** and **156** is thereby achieved.

The resonator conductor portion **1520** of the resonator **152** and the resonator conductor portion **1510** of the resonator **151** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **152** and **151** is thereby achieved easily.

The resonator conductor portion **1550** of the resonator **155** and the resonator conductor portion **1560** of the resonator **156** are physically adjacent to each other without any resonator conductor portion of another resonator therebetween. The capacitive coupling between the resonators **155** and **156** is thereby achieved easily.

The function and effects of the band-pass filter **100** according to the present embodiment will now be described. For example, the band-pass filter **100** is designed and configured to have a passband in a quasi-millimeter wave band of 10 to 30 GHz or a millimeter wave band of 30 to 300 GHz.

In the present embodiment, the partition **107** divides the space defined by the shield **6** into a space in which the resonator conductor portion **1520** is located and a space in which the resonator conductor portion **1550** is located. The present embodiment thus prevents the attenuation characteristic in the frequency region above the passband from being degraded by the lowest-order waveguide mode, like the first embodiment.

Further, in the present embodiment, the second stage resonator **152** and the fifth stage resonator **155**, which are not adjacent to each other in circuit configuration, are magnetically coupled to each other. The magnetic coupling between the resonators **152** and **155** enables creation of attenuation poles in both of the first and second passband-vicinity regions in the frequency response of the insertion loss, the first passband-vicinity region being close to the passband and lower than the passband, the second passband-vicinity region being close to the passband and higher than the passband.

In the present embodiment, the first stage resonator **151** and the sixth stage resonator **156**, which are not adjacent to each other in circuit configuration, are capacitively coupled to each other. The capacitive coupling between the resonators **151** and **156** has the effect of increasing the insertion loss at the attenuation pole occurring in the first passband-vicinity region. The magnitude of the insertion loss at the attenuation pole occurring in the first passband-vicinity

region is adjustable by adjusting the magnitude of the capacitive coupling between the resonators **151** and **156**. The coupling adjustment section **108** is provided to adjust the magnitude of the capacitive coupling between the resonators **151** and **156**. In other words, the magnitude of the capacitive coupling between the resonators **151** and **156** is adjustable by adjusting the number of and distance between the plurality of through hole lines **108T** constituting the coupling adjustment section **108**.

The present embodiment achieves such a characteristic that the insertion loss steeply changes in both of the first passband-vicinity region and the second passband-vicinity region, and in particular, achieves such a characteristic that the insertion loss changes more steeply in the first passband-vicinity region than in the second passband-vicinity region.

In the present embodiment, the partition **107** is disposed to pass between the resonator conductor portion **1520** and the resonator conductor portion **1550**. The resonator conductor portion **1520** and the resonator conductor portion **1550** respectively constitute the resonator **152** and the resonator **155**, which are magnetically coupled to each other although not adjacent to each other in circuit configuration. The magnetic coupling between the resonators **152** and **155** can be weaker than the electromagnetic coupling between any two resonators that are adjacent to each other in circuit configuration. According to the present embodiment, it is thus possible to establish magnetic coupling between the resonators **152** and **155** while disposing the partition **107** to pass between the resonator conductor portion **1520** and the resonator conductor portion **1550**. The present embodiment thus achieves both of prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode by the provision of the partition **107** and the creation of attenuation poles by establishing magnetic coupling between the resonators **152** and **155**. This results in the favorable characteristics of the band-pass filter **100**.

In the present embodiment, the resonator conductor portions **1510**, **1520**, **1550** and **1560** of the resonators **151**, **152**, **155** and **156** having the above-described relationship in circuit configuration are configured to have the above-described physical relationship. The present embodiment thus realizes the band-pass filter **100** which has two cross couplings and is simple in structure.

Now, an example of characteristics of the band-pass filter **100** according to the present embodiment and an example of characteristics of a band-pass filter of a second comparative example will be discussed. The band-pass filter of the second comparative example has the same configuration as that of the band-pass filter **100** except that the partition **107** is omitted.

FIG. **25** illustrates an example frequency response of the insertion loss of the band-pass filter **100** according to the present embodiment. FIG. **26** illustrates an example frequency response of the insertion loss of the band-pass filter of the second comparative example. The frequency responses shown in FIGS. **25** and **26** were obtained by simulation. In FIGS. **25** and **26**, the horizontal axis represents frequency, and the vertical axis represents insertion loss. In the examples shown in FIGS. **25** and **26**, the band-pass filter **100** and the band-pass filter of the second comparative example have a passband of approximately 26 to 30 GHz, and the center frequency of the passband is approximately 28 GHz.

For the band-pass filter **100** used in the simulation, the magnitudes of the two cross couplings were adjusted, based on the presence of the partition **107**, so as to obtain such a characteristic that the insertion loss steeply changes in both

of the first passband-vicinity region and the second passband-vicinity region, as shown in FIG. **25**. The first passband-vicinity region is a frequency region of approximately 24 to 26 GHz. The second passband-vicinity region is a frequency region of approximately 30 to 32 GHz. Note that the characteristic shown in FIG. **25** exhibits no apparent attenuation pole in the second passband-vicinity region. This is because the capacitive coupling between the resonators **151** and **156** caused a slight reduction in the insertion loss at an attenuation pole that was caused to occur in the second passband-vicinity region by the magnetic coupling between the resonators **152** and **155**. Although no apparent attenuation pole is observed in the second passband-vicinity region, the characteristic shown in FIG. **25** exhibits a steep change in the insertion loss in that region.

The characteristic of the band-pass filter of the second comparative example shown in FIG. **26** exhibits a lower insertion loss than that of the band-pass filter **100** in both of the first passband-vicinity region and the second passband-vicinity region. This is because, for the band-pass filter of the second comparative example, the omission of the partition **107** resulted in a deviation of the magnitude of the magnetic coupling between the resonators **152** and **155** from the adjusted magnitude in the band-pass filter **100**.

Further, the characteristic of the band-pass filter of the second comparative example shown in FIG. **26** exhibits a peak of an extreme reduction in the insertion loss in a frequency region near 50 GHz. This is considered to be due to unwanted resonance caused by the lowest-order waveguide mode. In the characteristic of the band-pass filter **100** shown in FIG. **25**, when compared with the characteristic shown in FIG. **26**, the peak present in the frequency region near 50 GHz is shifted to a higher frequency and the insertion loss at this peak is higher. Accordingly, the characteristic shown in FIG. **25** is better than the characteristic shown in FIG. **26** in terms of attenuation characteristic in a frequency region above the passband.

It is apparent from FIG. **25** that the band-pass filter **100** according to the present embodiment provides the favorable characteristics achieving steep changes in the insertion loss in both of the first and second passband-vicinity regions and prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode.

The configuration, operation and effects of the present embodiment are otherwise the same as those of the first embodiment.

### Third Embodiment

A third embodiment of the present invention will now be described with reference to FIG. **27** and FIG. **28**. FIG. **27** is a perspective view illustrating the structure of a band-pass filter according to the third embodiment. FIG. **28** is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the third embodiment.

The band-pass filter **200** according to the present embodiment includes the main body **2**, the first input/output port **3**, the second input/output port **4**, three or more resonators, the shield **6**, and a partition **207**. The main body **2** includes the multilayer stack **20**.

The three or more resonators are located between the first input/output port **3** and the second input/output port **4** in circuit configuration. In the present embodiment, the three or more resonators are three resonators **251**, **252** and **253**. The three resonators **251**, **252** and **253** are arranged in this order, from closest to farthest, from the first input/output port **3** in circuit configuration. The three resonators **251** to **253** are

configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration. Specifically, the resonators 251 to 253 are configured so that the resonators 251 and 252 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, and the resonators 252 and 253 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other. In the present embodiment, the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is specifically capacitive coupling. In the present embodiment, each of the resonators 251 to 253 is a resonator with open ends, and also a half-wave resonator.

The first portion 61, the second portion 62 and the connecting portion 63 of the shield 6 are arranged to surround the three resonators 251 to 253. The first portion 61 is formed of a first conductor layer 610 disposed on the first end face 21a of the main portion 21 of the multilayer stack 20. The second portion 62 is formed of a second conductor layer 620 disposed on the second end face 21b of the main portion 21 of the multilayer stack 20.

The band-pass filter 200 includes a capacitor C212 for establishing capacitive coupling between the resonators 251 and 252, and a capacitor C223 for establishing capacitive coupling between the resonators 252 and 253.

In the present embodiment, among the three resonators 251 to 253, the resonator 251, which is the closest to the first input/output port 3 in circuit configuration, and the resonator 253, which is the closest to the second input/output port 4 in circuit configuration, are magnetically coupled to each other although they are not adjacent to each other in circuit configuration. The resonator 251 corresponds to the first resonator in the present invention. The resonator 253 corresponds to the second resonator in the present invention.

The band-pass filter 200 further includes a capacitor C201 provided between the first input/output port 3 and the resonator 251, and a capacitor C202 provided between the second input/output port 4 and the resonator 253.

The band-pass filter 200 further includes the two lines 91 and 92 as in the first embodiment.

The resonator 251 includes a resonator conductor portion 2510 formed of a conductor. The resonator 252 includes a resonator conductor portion 2520 formed of a conductor. The resonator 253 includes a resonator conductor portion 2530 formed of a conductor. The resonator conductor portion 2510 corresponds to the first resonator conductor portion in the present invention. The resonator conductor portion 2530 corresponds to the second resonator conductor portion in the present invention.

The resonator conductor portions 2510, 2520 and 2530 are located at the same position in the multilayer stack 20 in the first direction, i.e., the Z direction. Each of the resonator conductor portions 2510, 2520 and 2530 extends in a direction intersecting the first direction or the Z direction. In the present embodiment, specifically, each of the resonator conductor portions 2510, 2520 and 2530 extends in a direction orthogonal to the first direction or the Z direction.

Each of the resonator conductor portions 2510, 2520 and 2530 has a first end and a second end opposite to each other. As mentioned above, each of the resonators 251 to 253 is a resonator with open ends. Thus, both of the first and second ends of each of the resonator conductor portions 2510, 2520 and 2530 are open. Each of the resonator conductor portions 2510, 2520 and 2530 has a length of one half or nearly one half the wavelength corresponding to the center frequency of the passband of the band-pass filter 200.

The partition 207 is in contact with the first portion 61 and the second portion 62. At least part of the partition 207 extends to pass between the resonator conductor portion 2510 and the resonator conductor portion 2530. In the present embodiment, specifically, the partition 207 extends in the first direction, i.e., the Z direction. The partition 207 connects the first portion 61 and the second portion 62 via the shortest path. To be more specific, the length of the partition 207 in the Z direction is equal to the distance between the first portion 61 and the second portion 62.

The partition 207 runs through the two or more dielectric layers constituting the main portion 21. In the present embodiment, the partition 207 includes a plurality of through hole lines 207T each running through the two or more dielectric layers constituting the main portion 21. The plurality of through hole lines 207T correspond to the plurality of first through hole lines in the present invention. In FIG. 27, each through hole line 207T is represented by a circular column. Each of the through hole lines 207T includes two or more through holes connected in series. Each of the through hole lines 207T extends in the Z direction.

In the present embodiment, the resonator conductor portion 2510 and the resonator conductor portion 2530 extend in the Y direction and are adjacent to each other in the X direction with a predetermined spacing therebetween. The through hole lines 207T are arranged to be adjacent to each other in the Y direction and pass between the resonator conductor portions 2510 and 2530. In the present embodiment, the number of the through hole lines 207T is six.

The connecting portion 63 of the shield 6 includes a plurality of through hole lines 263T each running through the two or more dielectric layers constituting the main portion 21. The plurality of through hole lines 263T correspond to the second through hole lines in the present invention. In FIG. 27, each through hole line 263T is represented by a circular column. All the through hole lines represented by circular columns in FIG. 27, except the six through hole lines 207T, are the through hole lines 263T. Each of the through hole lines 263T includes two or more through holes connected in series. Each of the through hole lines 263T extends in the Z direction.

The band-pass filter 200 further includes conductor layers 211, 212, 221 and 222 provided inside the multilayer stack 20.

The conductor layer 211 has a first end and a second end opposite to each other. A portion of the conductor layer 211 near the first end thereof is connected to the first input/output port 3 via a plurality of through holes provided in the multilayer stack 20. A portion of the conductor layer 211 near the second end thereof is opposed to a portion of the resonator conductor portion 2510 near the first end thereof with one or more dielectric layers interposed therebetween. The capacitor C201 is thereby formed. The line 91 is connected to the first input/output port 3 via one or more of the through holes connecting the conductor layer 211 and the first input/output port 3.

The conductor layer 212 has a first end and a second end opposite to each other. A portion of the conductor layer 212 near the first end thereof is connected to the second input/output port 4 via a plurality of through holes provided in the multilayer stack 20. A portion of the conductor layer 212 near the second end thereof is opposed to a portion of the resonator conductor portion 2530 near the first end thereof with one or more dielectric layers interposed therebetween. The capacitor C202 is thereby formed. The line 92 is connected to the second input/output port 4 via one or more

of the through holes connecting the conductor layer 212 and the second input/output port 4.

The conductor layer 221 is opposed to a portion of the resonator conductor portion 2510 near the second end thereof and to a portion of the resonator conductor portion 2520 near the first end thereof with one or more dielectric layers interposed between the conductor layer 221 and each of the aforementioned respective portions of the resonator conductor portions 2510 and 2520. The capacitor C212 is thereby formed.

The conductor layer 222 is opposed to a portion of the resonator conductor portion 2520 near the second end thereof and to a portion of the resonator conductor portion 2530 near the second end thereof with one or more dielectric layers interposed between the conductor layer 222 and each of the aforementioned respective portions of the resonator conductor portions 2520 and 2530. The capacitor C223 is thereby formed.

In the present embodiment, the partition 207 divides the space defined by the shield 6 into a space in which the resonator conductor portion 2510 is located and a space in which the resonator conductor portion 2530 is located. The present embodiment thus prevents the attenuation characteristic in the frequency region above the passband from being degraded by the lowest-order waveguide mode, like the first embodiment.

Further, in the present embodiment, the first stage resonator 251 and the third stage resonator 253, which are not adjacent to each other in circuit configuration, are magnetically coupled to each other. The magnetic coupling between the resonators 251 and 253 enables creation of an attenuation pole in the first passband-vicinity region, which is a frequency region close to the passband and lower than the passband, in the frequency response of the insertion loss.

By virtue of the above features, the band-pass filter 200 according to the present embodiment provides the favorable characteristics achieving steep changes in the insertion loss in the first passband-vicinity region and prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode.

The configuration, operation and effects of the present embodiment are otherwise the same as those of the first embodiment.

#### Fourth Embodiment

A fourth embodiment of the present invention will now be described with reference to FIG. 29 and FIG. 30. FIG. 29 is a perspective view illustrating the structure of a band-pass filter according to the fourth embodiment. FIG. 30 is a circuit diagram illustrating the circuit configuration of the band-pass filter according to the fourth embodiment.

The band-pass filter 300 according to the present embodiment includes the main body 2, the first input/output port 3, the second input/output port 4, three or more resonators, the shield 6, and a partition 307. The main body 2 includes the multilayer stack 20.

The three or more resonators are located between the first input/output port 3 and the second input/output port 4 in circuit configuration. In the present embodiment, the three or more resonators are four resonators 351, 352, 353 and 354. The four resonators 351, 352, 353 and 354 are arranged in this order, from closest to farthest, from the first input/output port 3 in circuit configuration. The four resonators 351 to 354 are configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration. Specifically, the resona-

tors 351 to 354 are configured so that the resonators 351 and 352 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, the resonators 352 and 353 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other, and the resonators 353 and 354 are adjacent to each other in circuit configuration and are electromagnetically coupled to each other. In the present embodiment, the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is specifically capacitive coupling. In the present embodiment, each of the resonators 351 to 354 is a resonator with open ends, and also a half-wave resonator.

The first portion 61, the second portion 62 and the connecting portion 63 of the shield 6 are arranged to surround the four resonators 351 to 354. The first portion 61 is formed of the first conductor layer 610 disposed on the first end face 21a of the main portion 21 of the multilayer stack 20. The second portion 62 is formed of the second conductor layer 620 disposed on the second end face 21b of the main portion 21 of the multilayer stack 20.

The band-pass filter 300 includes a capacitor C312 for establishing capacitive coupling between the resonators 351 and 352, a capacitor C323 for establishing capacitive coupling between the resonators 352 and 353, and a capacitor C334 for establishing capacitive coupling between the resonators 353 and 354.

In the present embodiment, among the four resonators 351 to 354, the resonator 351, which is the closest to the first input/output port 3 in circuit configuration, and the resonator 354, which is the closest to the second input/output port 4 in circuit configuration, are magnetically coupled to each other although they are not adjacent to each other in circuit configuration. The resonator 351 corresponds to the first resonator in the present invention. The resonator 354 corresponds to the second resonator in the present invention.

The band-pass filter 300 further includes a capacitor C301 provided between the first input/output port 3 and the resonator 351, and a capacitor C302 provided between the second input/output port 4 and the resonator 354.

The band-pass filter 300 further includes the two lines 91 and 92 as in the first embodiment.

The resonator 351 includes a resonator conductor portion 3510 formed of a conductor. The resonator 352 includes a resonator conductor portion 3520 formed of a conductor. The resonator 353 includes a resonator conductor portion 3530 formed of a conductor. The resonator 354 includes a resonator conductor portion 3540 formed of a conductor. The resonator conductor portion 3510 corresponds to the first resonator conductor portion in the present invention. The resonator conductor portion 3540 corresponds to the second resonator conductor portion in the present invention.

The resonator conductor portions 3510, 3520, 3530 and 3540 are located at the same position in the multilayer stack 20 in the first direction, i.e., the Z direction. Each of the resonator conductor portions 3510, 3520, 3530 and 3540 extends in a direction intersecting the first direction or the Z direction. In the present embodiment, specifically, each of the resonator conductor portions 3510, 3520, 3530 and 3540 extends in a direction orthogonal to the first direction or the Z direction.

Each of the resonator conductor portions 3510, 3520, 3530 and 3540 has a first end and a second end opposite to each other. As mentioned above, each of the resonators 351 to 354 is a resonator with open ends. Thus, both of the first and second ends of each of the resonator conductor portions 3510, 3520, 3530 and 3540 are open. Each of the resonator

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conductor portions **3510**, **3520**, **3530** and **3540** has a length of one half or nearly one half the wavelength corresponding to the center frequency of the passband of the band-pass filter **300**.

The partition **307** is in contact with the first portion **61** and the second portion **62**. At least part of the partition **307** extends to pass between the resonator conductor portion **3510** and the resonator conductor portion **3540**. In the present embodiment, specifically, the partition **307** extends in the first direction, i.e., the Z direction. The partition **307** connects the first portion **61** and the second portion **62** via the shortest path. To be more specific, the length of the partition **307** in the Z direction is equal to the distance between the first portion **61** and the second portion **62**.

The partition **307** runs through the two or more dielectric layers constituting the main portion **21**. In the present embodiment, the partition **307** includes a plurality of through hole lines **307T** each running through the two or more dielectric layers constituting the main portion **21**. The plurality of through hole lines **307T** correspond to the plurality of first through hole lines in the present invention. In FIG. **29**, each through hole line **307T** is represented by a circular column. Each of the through hole lines **307T** includes two or more through holes connected in series. Each of the through hole lines **307T** extends in the Z direction.

In the present embodiment, the resonator conductor portion **3510** and the resonator conductor portion **3540** extend in the Y direction and are adjacent to each other in the X direction with a predetermined spacing therebetween. The through hole lines **307T** are arranged to be adjacent to each other in the Y direction and pass between the resonator conductor portions **3510** and **3540**. In the present embodiment, the number of the through hole lines **307T** is six.

The connecting portion **63** of the shield **6** includes a plurality of through hole lines **363T** each running through the two or more dielectric layers constituting the main portion **21**. The plurality of through hole lines **363T** correspond to the second through hole lines in the present invention. In FIG. **29**, each through hole line **363T** is represented by a circular column. All the through hole lines represented by circular columns in FIG. **29**, except the six through hole lines **307T**, are the through hole lines **363T**. Each of the through hole lines **363T** includes two or more through holes connected in series. Each of the through hole lines **363T** extends in the Z direction.

The band-pass filter **300** further includes conductor layers **311**, **312**, **321**, **322** and **323** provided inside the multilayer stack **20**.

The conductor layer **311** has a first end and a second end opposite to each other. A portion of the conductor layer **311** near the first end thereof is connected to the first input/output port **3** via a plurality of through holes provided in the multilayer stack **20**. A portion of the conductor layer **311** near the second end thereof is opposed to a portion of the resonator conductor portion **3510** near the first end thereof with one or more dielectric layers interposed therebetween. The capacitor **C301** is thereby formed. The line **91** is connected to the first input/output port **3** via one or more of the through holes connecting the conductor layer **311** and the first input/output port **3**.

The conductor layer **312** has a first end and a second end opposite to each other. A portion of the conductor layer **312** near the first end thereof is connected to the second input/output port **4** via a plurality of through holes provided in the multilayer stack **20**. A portion of the conductor layer **312** near the second end thereof is opposed to a portion of the

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resonator conductor portion **3540** near the first end thereof with one or more dielectric layers interposed therebetween. The capacitor **C302** is thereby formed. The line **92** is connected to the second input/output port **4** via one or more of the through holes connecting the conductor layer **312** and the second input/output port **4**.

The conductor layer **321** is opposed to a portion of the resonator conductor portion **3510** near the second end thereof and to a portion of the resonator conductor portion **3520** near the first end thereof with one or more dielectric layers interposed between the conductor layer **321** and each of the aforementioned respective portions of the resonator conductor portions **3510** and **3520**. The capacitor **C312** is thereby formed.

The conductor layer **322** is opposed to a portion of the resonator conductor portion **3520** near the first end thereof and to a portion of the resonator conductor portion **3530** near the first end thereof with one or more dielectric layers interposed between the conductor layer **322** and each of the aforementioned respective portions of the resonator conductor portions **3520** and **3530**. The capacitor **C323** is thereby formed.

The conductor layer **323** is opposed to a portion of the resonator conductor portion **3530** near the first end thereof and to a portion of the resonator conductor portion **3540** near the second end thereof with one or more dielectric layers interposed between the conductor layer **323** and each of the aforementioned respective portions of the resonator conductor portions **3530** and **3540**. The capacitor **C334** is thereby formed.

In the present embodiment, the partition **307** divides the space defined by the shield **6** into a space in which the resonator conductor portion **3510** is located and a space in which the resonator conductor portion **3540** is located. The present embodiment thus prevents the attenuation characteristic in the frequency region above the passband from being degraded by the lowest-order waveguide mode, as does the first embodiment.

In the present embodiment, the first stage resonator **351** and the fourth stage resonator **354**, which are not adjacent to each other in circuit configuration, are magnetically coupled to each other. The magnetic coupling between the resonators **351** and **354** enables creation of attenuation poles in both of the first and second passband-vicinity regions in the frequency response of the insertion loss, the first passband-vicinity region being close to the passband and lower than the passband, the second passband-vicinity region being close to the passband and higher than the passband.

By virtue of the above features, the band-pass filter **300** according to the present embodiment provides the favorable characteristics achieving steep changes in the insertion loss in both of the first and second passband-vicinity regions and prevention of deterioration in the attenuation characteristic associated with the lowest-order waveguide mode.

The configuration, operation and effects of the present embodiment are otherwise the same as those of the first embodiment.

The present invention is not limited to the foregoing embodiments, and various modifications may be made thereto. For example, the number and the configuration of the resonators are not limited to those illustrated in the foregoing embodiments, and can be freely chosen as far as the requirements of the appended claims are met. Further, at least part of the connecting portion of the shield **6** may be composed of conductor layer(s) formed on one or more side surfaces of the main body **2**, instead of a plurality of through

hole lines. Still further, the partition may be composed of plate-shaped conductor portions, instead of a plurality of through hole lines.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. Thus, it is to be understood that, within the scope of the appended claims and equivalents thereof, the invention may be practiced in other embodiments than the foregoing most preferable embodiments.

What is claimed is:

1. A band-pass filter comprising:
  - a main body formed of a dielectric;
  - a first input/output port and a second input/output port integrated with the main body;
  - three or more resonators provided within the main body, located between the first input/output port and the second input/output port in circuit configuration, and configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration;
  - a shield formed of a conductor and integrated with the main body; and
  - a partition formed of a conductor, provided within the main body, and electrically connected to the shield, wherein:
    - the shield includes a first portion and a second portion spaced from each other in a first direction, and a connecting portion connecting the first and second portions,
    - the first portion, the second portion and the connecting portion are arranged to surround the three or more resonators,
    - the three or more resonators include a first resonator and a second resonator that are configured to be magnetically coupled to each other although not adjacent to each other in circuit configuration,
    - the first resonator includes a first resonator conductor portion formed of a conductor,
    - the second resonator includes a second resonator conductor portion formed of a conductor,
    - each of the first and second resonator conductor portions extends in a direction intersecting the first direction,
    - the partition is in contact with the first portion and the second portion,
    - at least part of the partition extends to pass between the first resonator conductor portion and the second resonator conductor portion, and
    - each of the three or more resonators is a resonator with open ends.
2. The band-pass filter according to claim 1, wherein the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is capacitive coupling.
3. The band-pass filter according to claim 1, further comprising a notch filter section for attenuating a signal of a predetermined frequency higher than a passband of the band-pass filter.
4. The band-pass filter according to claim 1, wherein the partition extends in the first direction and connects the first portion and the second portion via a shortest path.
5. The band-pass filter according to claim 1, wherein the first resonator is a resonator that is the closest to the first input/output port in circuit configuration, and the second resonator is a resonator that is the closest to the second input/output port in circuit configuration.
6. The band-pass filter according to claim 5, wherein the three or more resonators are five resonators.

7. The band-pass filter according to claim 1, wherein the first resonator is a resonator that is the second closest to the first input/output port in circuit configuration, and
  - the second resonator is a resonator that is the second closest to the second input/output port in circuit configuration.
8. The band-pass filter according to claim 7, wherein the three or more resonators are six resonators.
9. A band-pass filter comprising:
  - a main body formed of a dielectric;
  - a first input/output port and a second input/output port integrated with the main body;
  - three or more resonators provided within the main body, located between the first input/output port and the second input/output port in circuit configuration, and configured so that electromagnetic coupling is established between every two of the resonators adjacent to each other in circuit configuration;
  - a shield formed of a conductor and integrated with the main body; and
  - a partition formed of a conductor, provided within the main body, and electrically connected to the shield, wherein:
    - the shield includes a first portion and a second portion spaced from each other in a first direction, and a connecting portion connecting the first and second portions,
    - the first portion, the second portion and the connecting portion are arranged to surround the three or more resonators,
    - the three or more resonators include a first resonator and a second resonator that are configured to be magnetically coupled to each other although not adjacent to each other in circuit configuration,
    - the first resonator includes a first resonator conductor portion formed of a conductor,
    - the second resonator includes a second resonator conductor portion formed of a conductor,
    - each of the first and second resonator conductor portions extends in a direction intersecting the first direction, at least part of the partition extends to pass between the first resonator conductor portion and the second resonator conductor portion,
    - the main body includes a multilayer stack composed of a plurality of dielectric layers stacked together in the first direction,
    - the first resonator conductor portion and the second resonator conductor portion are located at the same position in the multilayer stack in the first direction, and the partition extends through two or more dielectric layers stacked together, among the plurality of dielectric layers, and is in contact with the first portion and the second portion.
10. The band-pass filter according to claim 9, further comprising a notch filter section for attenuating a signal of a predetermined frequency higher than a passband of the band-pass filter.
11. The band-pass filter according to claim 9, wherein the multilayer stack includes a main portion composed of the two or more dielectric layers, the main portion has a first end face and a second end face located at opposite ends in the first direction, the first portion is formed of a first conductor layer disposed on the first end face, and the second portion is formed of a second conductor layer disposed on the second end face.

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12. The band-pass filter according to claim 11, wherein the partition includes a plurality of first through hole lines each running through the two or more dielectric layers, and

each of the plurality of first through hole lines includes two or more through holes connected in series.

13. The band-pass filter according to claim 11, wherein the connecting portion of the shield includes a plurality of second through hole lines each running through the two or more dielectric layers, and

each of the plurality of second through hole lines includes two or more through holes connected in series.

14. The band-pass filter according to claim 9, wherein the first resonator is a resonator that is the second closest to the first input/output port in circuit configuration, and

the second resonator is a resonator that is the second closest to the second input/output port in circuit configuration.

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15. The band-pass filter according to claim 14, wherein the three or more resonators are six resonators.

16. The band-pass filter according to claim 9, wherein each of the three or more resonators is a resonator with open ends.

17. The band-pass filter according to claim 9, wherein the partition extends in the first direction and connects the first portion and the second portion via a shortest path.

18. The band-pass filter according to claim 9, wherein the first resonator is a resonator that is the closest to the first input/output port in circuit configuration, and the second resonator is a resonator that is the closest to the second input/output port in circuit configuration.

19. The band-pass filter according to claim 18, wherein the three or more resonators are five resonators.

20. The band-pass filter according to claim 9, wherein the electromagnetic coupling between every two of the resonators adjacent to each other in circuit configuration is capacitive coupling.

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